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UNITED TECHNOLOGIES RESEARCH CENTER
East Hartford, Connecticut 06108

EXPERIMENTAL INVESTIGATION OF TURBINE DISK CAVITY AERODYNAMICS AND HEAT TRANSFER

Final Report

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United Technologies Research Center
East Hartford, CT 06108

Contract NAS8-37462
May 1993

For
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GEORGE C. MARSHALL SPACE FLIGHT CENTER
MARSHALL SPACE FLIGHT CENTER, AL 35812

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FOREWORD

This report covers work performed under NASA Contract NAS8-37462. The objective of the work performed was to define the nature of the aerodynamics and heat transfer of the flow within the disk cavities and blade attachments of a large scale model simulating the SSME High Pressure Fuel Turbopump drive turbine. The NASA Program Manager is Dr. Paul McConnaughey of the George C. Marshall Space Flight Center. Acknowledgements are given to Mr. J. L. Kettle for the design of the large-scale model and to Ms. S. B. Orr for the preparation of the report figures and data tables.

Experimental Investigation of Turbine Disk Cavity Aerodynamics and Heat Transfer

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Experimental Investigation of Turbine Disk Cavity Aerodynamics and Heat Transfer

1.0 SUMMARY

The United Technologies Research Center (UTRC) conducted an experimental investigation of turbine disk cavity aerodynamics and heat transfer. The objective of this program was to provide an experimental data base that can guide the aerodynamic and thermal design of turbine disks and blade attachments for flow conditions and geometries simulating those of SSME turbopump drive turbines. A series of experiments was conducted to define the nature of the aerodynamics and heat transfer of the flow within the disk cavities and blade attachments of a large scale model simulating the SSME turbopump drive turbines. These experiments explored each of the various important aerodynamic driving mechanisms including (1) flow between the main gas path and the disk cavities, (2) flow within the disk cavities, (3) leakage flows through the blade attachments and labyrinth seals, and (4) the role that each of these various flows has in determining the adiabatic recovery temperature at all of the critical locations within the cavities. Critical to this program was (1) the requirement to provide close geometric simulation of the entire multi-disk cavity flow region, (2) the ability to simulate each of the disk cavity flow sources and sinks, (3) the ability to attain Reynolds numbers applicable to the SSME, and (4) the ability to obtain extensive local measurements on both the rotating and non-rotating components. Air was used to simulate the combustion products in the gas path. Air and carbon dioxide were used to simulate the coolants injected at three locations in the disk cavities. Trace amounts of carbon dioxide were used to determine the source of the gas at selected locations on the rotors, the cavity walls and the interstage seal.

The measurements on the rotor and stationary walls in the forward and aft cavities showed that the coolant effectiveness was 90 percent or greater when the coolant flow rate was greater than the local free disk entrainment flow rate and when room temperature air was used as both coolant and gas path fluid. When a coolant-to-gas-path density ratio of 1.51 was used in the aft cavity, the coolant effectiveness on the rotor was also 90 percent or greater at the aforementioned condition. However, the coolant concentration on the stationary wall was 60 to 80 percent at the aforementioned condition indicating a more rapid mixing of the coolant and flow through the rotor shank passages. This increased mixing rate was attributed to the destabilizing effects of the adverse density gradients.

2.0 INTRODUCTION

The NASA Space Shuttle Main Engine (SSME) project has the responsibility of providing the shuttle program with a reliable, reusable, high performance rocket engine. This study was directed toward supporting the NASA effort with an experimental investigation of turbopump drive turbine disk cavity aerodynamics and heat transfer. The study was directed toward determining the sources of the flow at selected locations within the High Pressure Fuel TurboPump (HPFTP) drive turbine disks and disk cavities (Fig. 2-1).

The source of the flow at a given location within the disk cavity system is not readily apparent for most turbines with coolant flows and rim cavity seals. This uncertainly occurs because of (1) the complex flow patterns within the cavity driven by the turbine disk, (2) the complex interactions between the main gas paths flow and the coolant flow through the turbine rim cavity seals, and (3) the coolant flow interactions with several components before entering the disk cavity. The gas source distribution at a given location will also vary with (4) coolant supply rates or pressure at each of the three coolant sources, (5) the main stream gas path operating conditions, and (6) the rim cavity seal geometry. Thus, the fluid at a given location has several different sources and a temperature which is determined by the contribution and temperature of each source as well as the heat transfer along the flowpaths from each source.

The sources of gas path and coolant flow for the SSME HPFTP turbine cavity are shown on Fig. 2-2. This study focused on determining the fraction of gas at selected locations within the cavity which is obtained from each of the possible sources: coolant supplies or main gas path flows. The data can then be used to estimate the adiabatic gas temperature at selected locations within the disk cavity and on the blade attachment components. Results from this Experimental Investigation of Turbine Disk Cavity Aerodynamics and Heat Transfer provide an experimental data base that can guide the aerodynamic and thermal design of turbine disks and blade attachments for flow conditions and geometries similar to those on the SSME turbopump drive turbine.

The experimental data base was obtained with large-scale (2x) models of the current drive-turbine disks and cavities. The experiments focused on determining the source of fluid at selected locations within the disk cavities, on the rotating disk structures and within the blade shanks. These experiments explored the various aerodynamic driving mechanisms including (1) flow between the main gas path and the disk cavities, (2) flow within the disk cavities, (3) leakage flows through the blade attachments and labyrinth seals, (4) effects of coolant density, and (5) the role that each of these various flows has in determining the adiabatic recovery temperature at all of the critical locations within the cavities. Critical to this program was the requirement to provide close geometric simulation of the entire multi-disk cavity flow region accurate clearance measurements, the ability to simulate each of the disk cavity flow sources and sinks, and the ability to obtain extensive local measurements on both the rotating and non-rotating components.

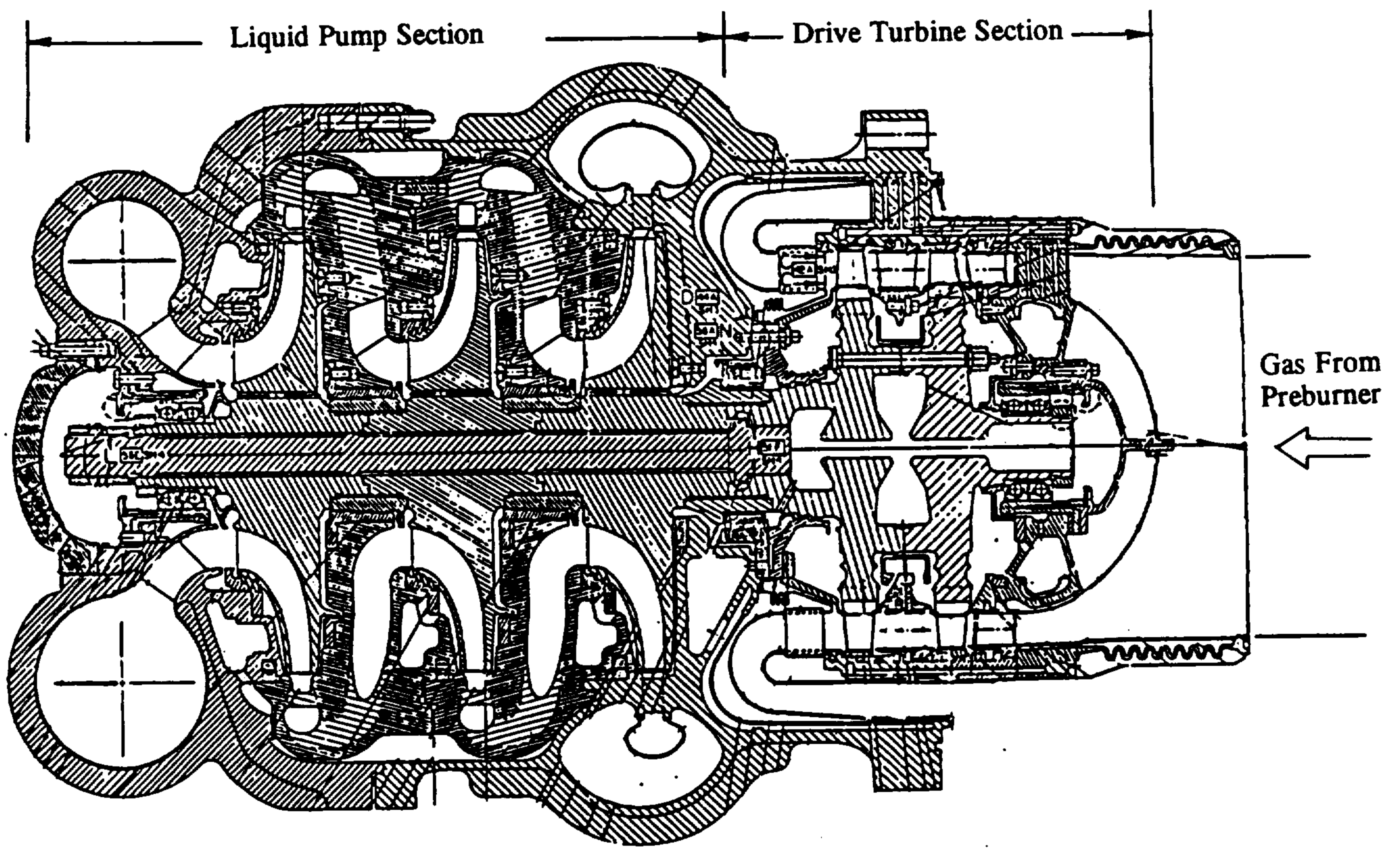


Figure 2-1. Cross Section of Current SSME Fuel Turbopump

Exploded View of Figure 2-1

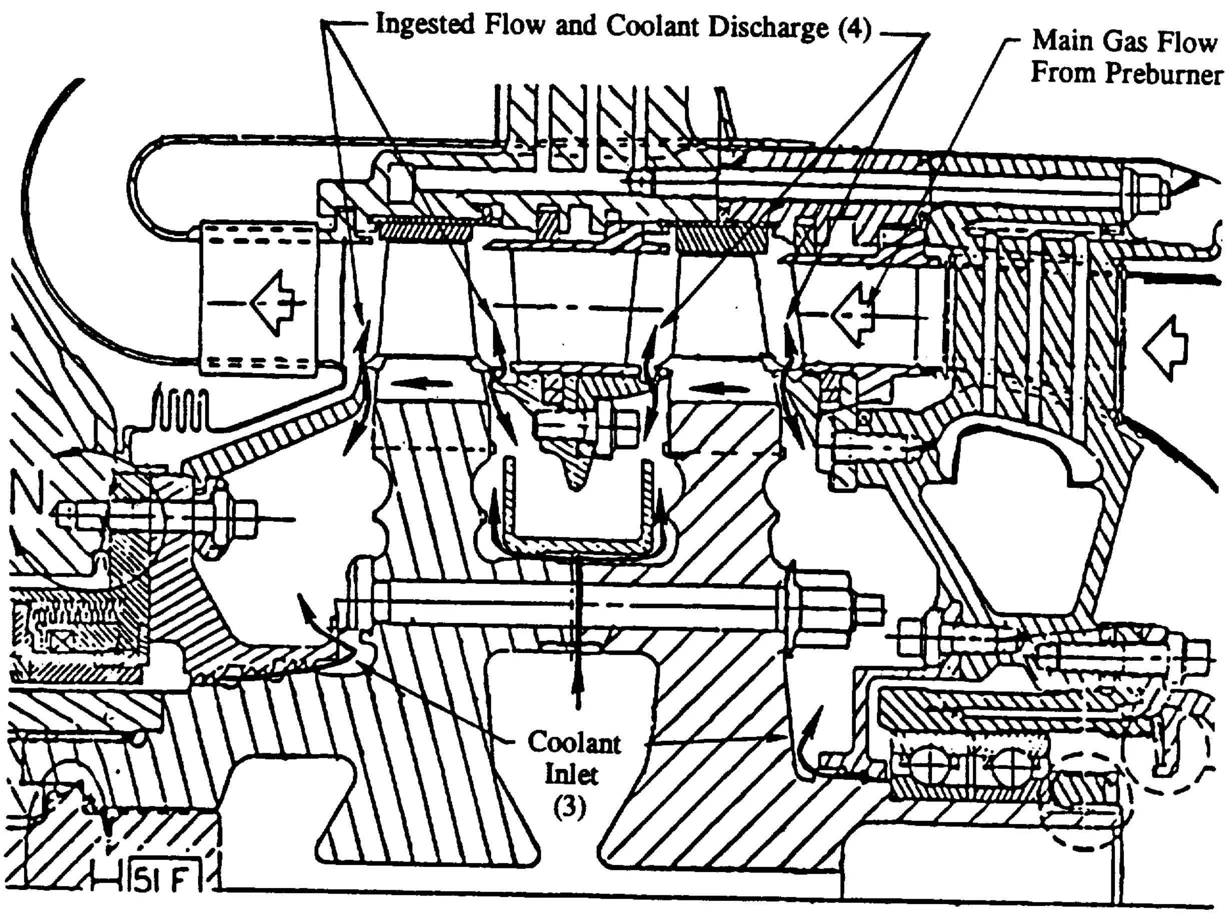


Figure 2-2. Flow Path in Drive Turbine Section of Current SSME Fuel Turbopump

3.0 DESCRIPTION OF MODEL, FACILITY, AND INSTRUMENTATION

The experiments were carried out in the Internal Flow Systems Facility at the United Technologies Research Center (UTRC). This facility was designed for experimental investigations of aerodynamic and heat transfer characteristics of internal air management systems of a number of turbomachinery components including compressor rotors, turbine disks, turbine disk cavities, rim cavity and seal systems and rotating orifices. The facility has two independently operated drive systems capable of simulating co-rotating and counter-rotating disk system designs. The facility has been used for a number of investigations of aerodynamics and heat transfer problems and more detailed information about the facility can be found in References 1-4.

A large-scale (2x) model of the disk cavities and disks associated with a fuel turbopump drive turbine was designed, fabricated and instrumented for use in the Internal Flow Systems Facility. The model duplicated the geometry of the disk, cavity, seals and the blade attachment. However, the model employs a simplified representation of the main gas path flow through the blades and vanes adjacent to the rim cavity. The geometric simulation of the model was based on assembly and detail fabrication drawings supplied by the NASA technical program manager.

Following are descriptions of the model, the facility and the model instrumentation. The seal clearances are also discussed in a separate subsection.

3.1 Model

A drawing of the model is shown in Fig. 3-1. The model consists of the outer case, with manifolds and simulated gas-path flow passages, the rotor, and the manifold system.

Outer Case

The casing surrounding the large-scale model rotating disks (Fig. 3-1) is comprised of nine (9) stationary disks. These stationary disks have an outer diameter of 28 in. The inner surface of the disks are contoured to form passages for the simulated gas paths over the rim seal regions. The flow paths across each rim seal (Fig. 3-2) are shaped to provide either a tangential velocity component or an axial flow depending upon the desired ratio of tangential to axial velocity across a particular rim seal. In this report, the following three aspects of the casing design are discussed: (1) gas path simulation, (2) axial load casing structure, (3) assembly and tolerance buildup.

Gas Path Simulation – The gas path in the model was simulated with axisymmetric flows through relatively narrow gaps as shown in Figs. 3-1 and 3-2. The flow through these gaps had approximately the same ratio of tangential to axial velocity as the flow across each seal in the full-scale SSME HPFTP. Because the flow at the exit of both the first and second rotor blades of the SSME HPFTP is approximately axial (without rotation), the gas path exit flow from both stages (between first Blade and second Vane and downstream of second Blade) was simulated with axial flow.

The flow across each seal was simulated by a separate air source and sink (inlet and exit) so that the source of gas within each cavity could be identified (Fig. 3-2). The difference between the flow rate injected and withdrawn in the simulated gas path surrounding each seal,

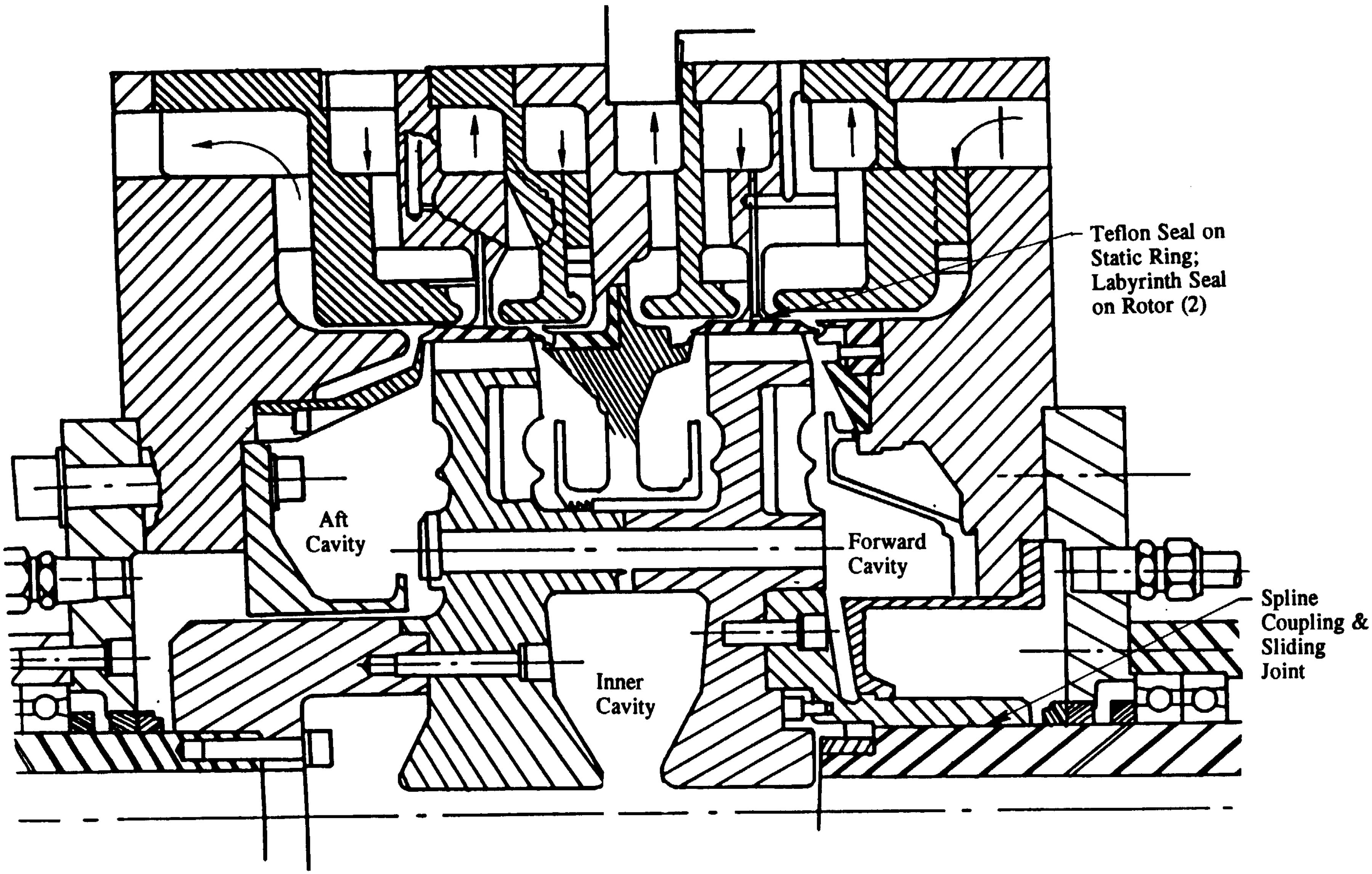


Figure 3-1. Large-Scale Model of SSME HPFTP Disks and Cavities

Flow Simulation	Source	Exit	Gas
Rim Seal 1 between first vane and first blade	1	2	Air
Rim Seal 2 between first blade and second vane	3	4	Air
Rim Seal 3 between second vane and second blade	5	6	Air
Rim Seal 4 downstream of second blade	7	8&9	Air
Foward Cavity Coolant Flow	12	-	Air
Inner Cavity Coolant Flow	13	-	Air
Aft Cavity Coolant Flow	14	-	Air or CO_2
Isolation Seals Bleed Flow	-	10&11	-

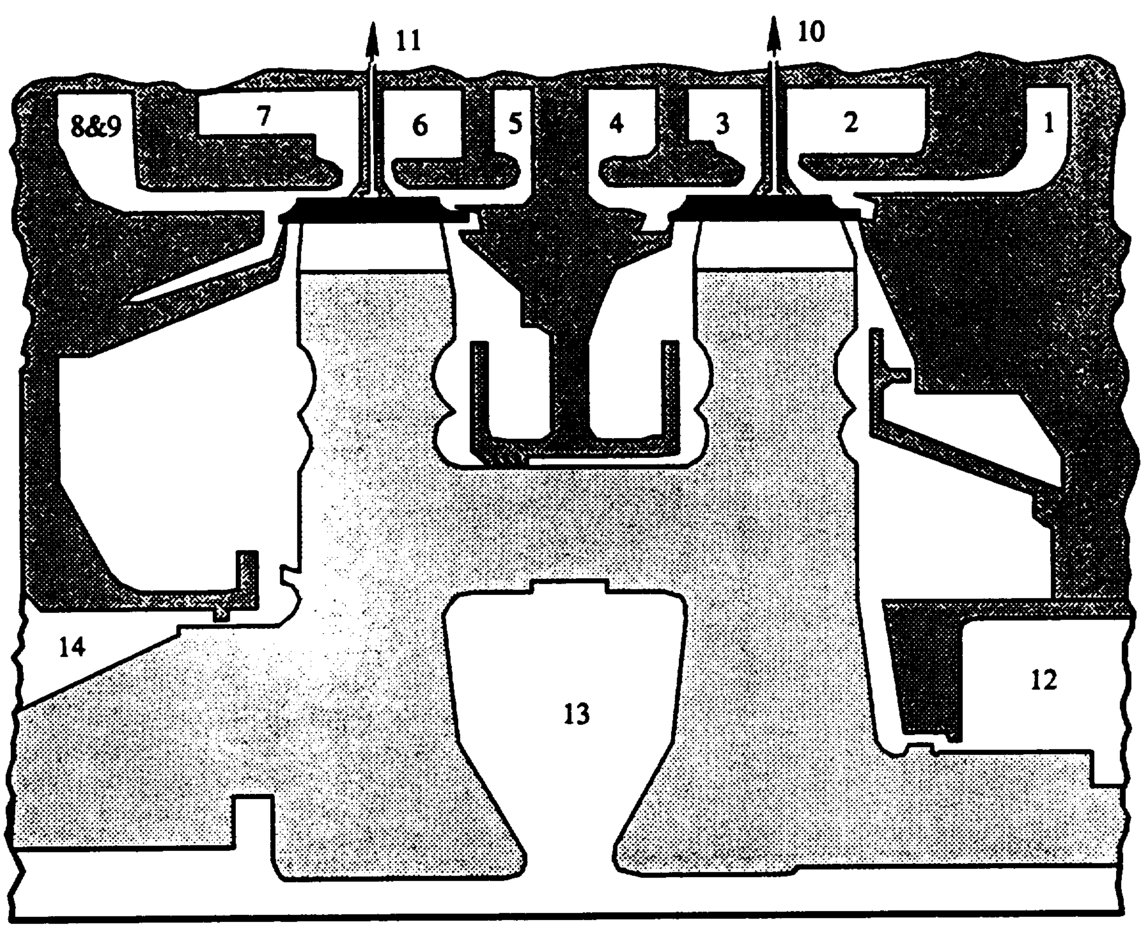


Figure 3-2. Gas Sources and Exits for Simulation of Flows in Model

$\dot{m}$, was the flow ingested or expelled through that seal. Each seal flow was kept free of any influence (contamination) from any of the other seal flows by two Teflon seals located at the top of each simulated disk blade platform. A cavity located between the Teflon seals was used to control the pressure ratio across the disks. This was accomplished by bleeding a small amount of air out of the cavity. This small bleed flow also kept any Teflon seal leakage from contaminating the disk downstream seal. The geometry of this cavity and the Teflon seal arrangement is shown in Fig. 4.1. The gas path flows were isolated from each other because a trace gas was added to each of the four streams during separate portions of a test and it was necessary to prevent the gases from different sources from mixing outside the disk cavity region.

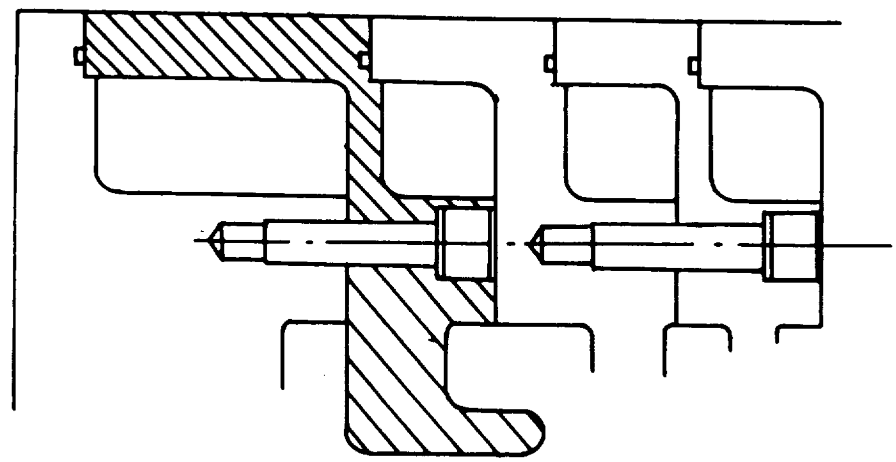
Axial Load Casing Structure – The nine stationary disks were assembled in a sequence with the rotating disks. Modest strength fasteners are required to hold the disks in place before the casing is pressurized. However, pressurization of the cavity up to 135 psig causes total axial loads of 80 to 85,000 pounds on the structure. A two-tier system of accommodating the axial loads was developed to handle this problem. During assembly, the disks were fastened to the adjacent disk with cap head screws as shown in Fig. 3-3a and -b. After the case was assembled, tie bolts (Fig. 3-3c) were used to hold all the components together. The tie bolts were prestressed such that pressurization of the cavity to full operating pressure did not cause separations between the disks. O-rings were used to seal the leakage paths between the disks and the tie bolts. Commercial "bolt seals" were used to seal the leakage paths around the bolt heads. The outer diameter of the disks was also sealed with O-rings.

Assembly and Tolerance Buildup – The large-scale model was designed with a bearing and support system different than the SSME HPFTP design. The primary difference was that the large-scale model had bearings at both ends of the rotor which were firmly attached to the casing. The benefit of this design is that the rotor radial location and the gaps between each radial seal were known within approximately 0.001 inch. The design requires one sliding joint so that the components (1) can expand axially due to temperature differences, and (2) can be manufactured with reasonable tolerances and installed without binding. The sliding joint occurred along the right-hand drive shaft as shown in Fig. 3-1. Note that the left-hand drive shaft was attached to the rotor disks with bolted components. The right-hand drive shaft was connected to the rotor disks with a long bushing to keep the shaft and rotor aligned and with a sliding fit between the bushing and the shaft. The bushing was driven by the shaft through a splined coupling. This design permitted (1) the alignment of each disk, rotor and seal during the assembly, (2) the measurement of radial and axial clearances at each seal during assembly, and (3) a bearing support structure with close tolerances.

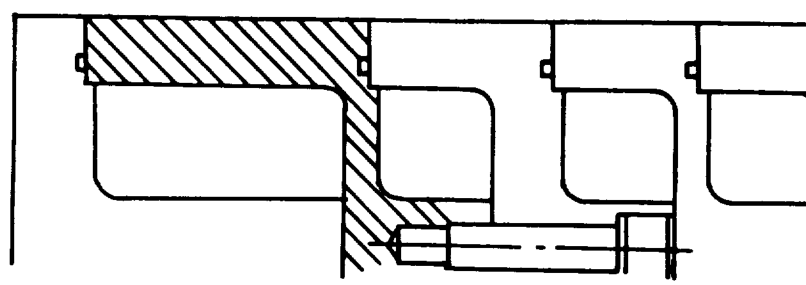
Rotor

A photograph of the rotor prior to final assembly, is shown in Figs. 3-4a & b. Note the tie bolts and nuts used to assemble the SSME HPFTP rotors are included as well as the blade shank shape and intershank spacing. The labyrinth seals on the outer portion of the rotor were used to isolate the flows simulating the flow across the rim seals on both sides of each rotor. The pressure in the cavity, between the two sets of 3 labyrinth seals upstream on each rotor, was maintained at a value less than the gas path pressure on either side of the seals by withdrawing a small amount of flow from the cavity region (gas exits 10 and 11 - Fig. 3-2). The labyrinth seals were imbedded into a strip of teflon by installing the rotor when cooled with liquid nitrogen. The result was a near interference fit on these isolation seals for most operating conditions.

a) Partial Section at 15 deg cw of TDC (typical every 60 deg)



b) Partial Section at 45 deg cw of TDC (typical every 60 deg)



c) Partial Section at TDC (typical every 60 deg)

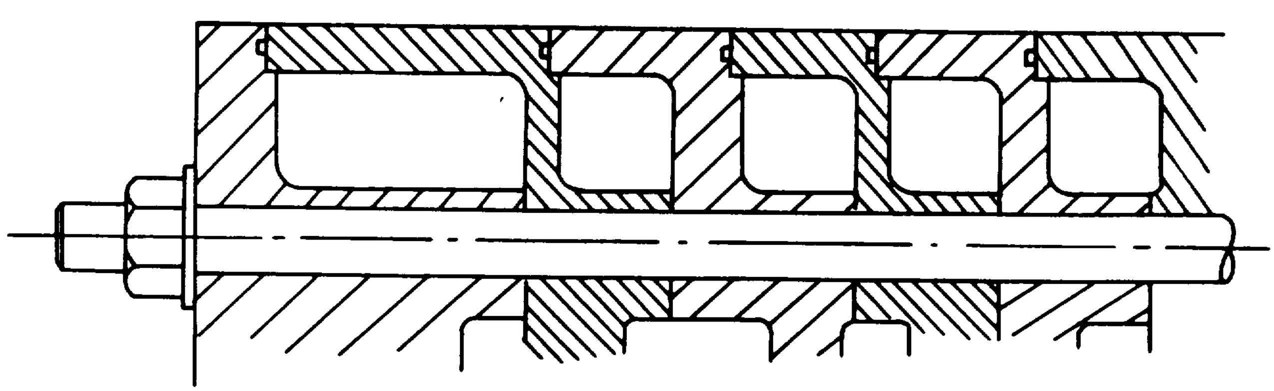


Figure 3-3. Casing Construction of Large-Scale Model of SSME HPFTP Disks and Cavities

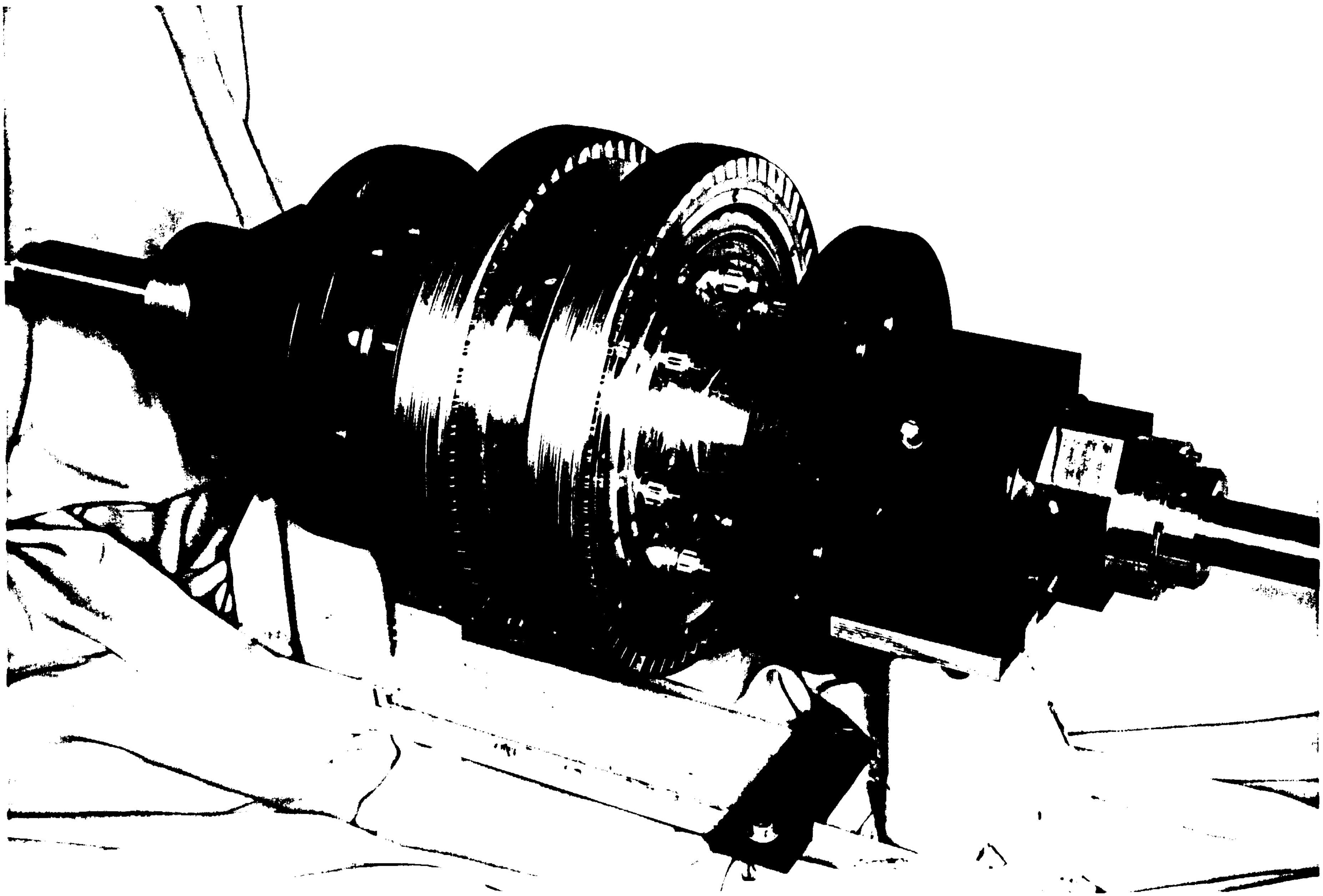


Figure 3-4a. Oblique Side View Photograph of Large-Scale Model Rotor

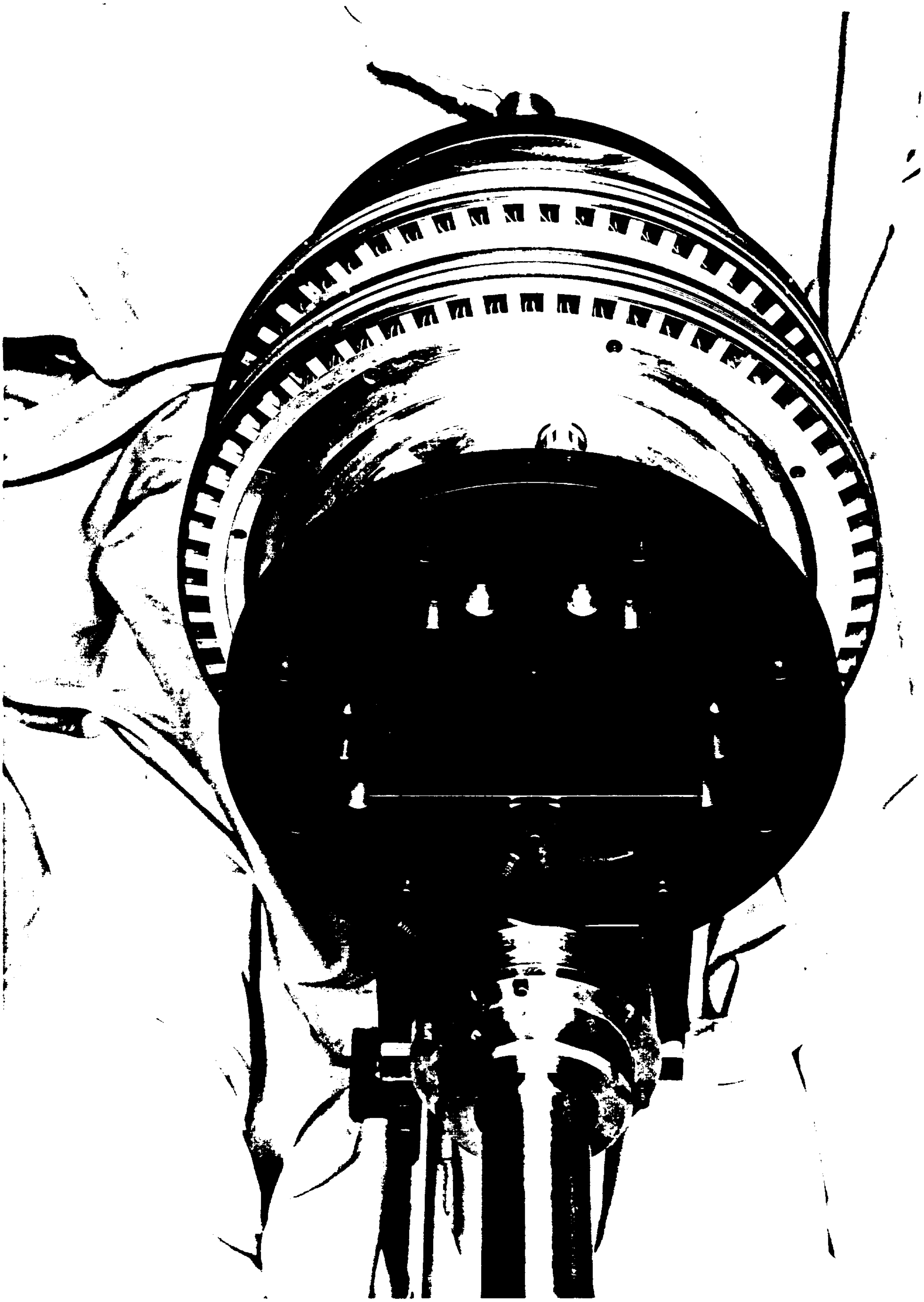


Figure 3-4b. Oblique End View of Large-Scale Model Rotor

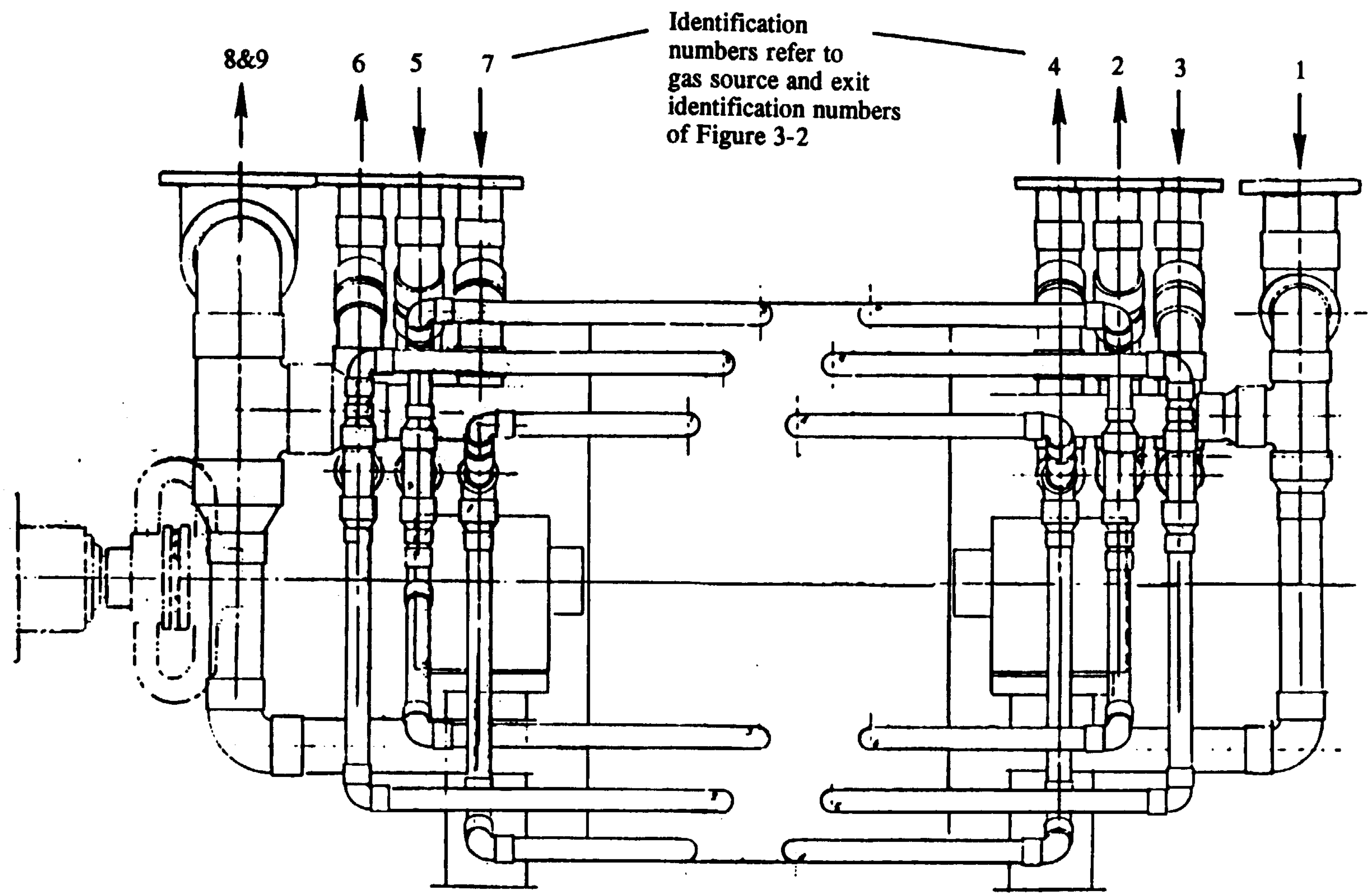


Figure 3-5. Manifold and Ducting Arrangement for Large-Scale Model of SSME HPFTP Disks and Cavities

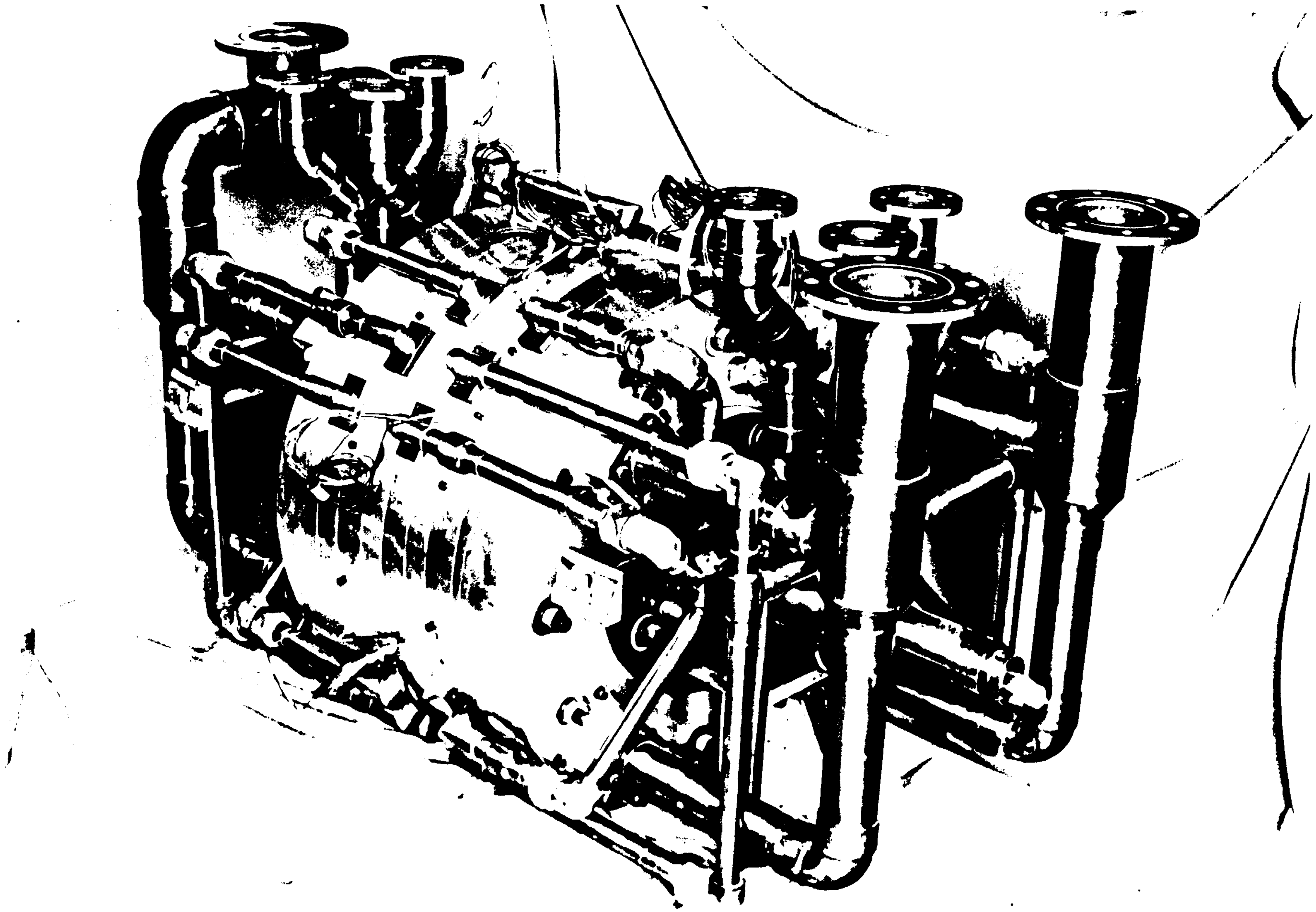


Figure 3-6. Photograph of Manifold and Ducting Arrangement

Manifold

The air management system for the large-scale model required seven inlet ducts and four outlet ducts (Fig. 3-5). The flow through each duct was metered and controlled to simulate one of the coolant flows or the main gas path flows across one of the four rim seals - Seals 1 through 4 in Fig. 3-7. The manifold and ducting arrangement for the air simulating the main gas path flows is shown in Fig. 3-5. The ducts were sized to provide the gas path flows and the flow ingested through each rim seal. The ducting arrangement is compact and fit within the UTRC Internal Air System Facility.

A photograph of the model with the manifolds attached is shown in Fig. 3-6.

Seals and Clearances

The rim seal clearances and locations for the model were calculated from Rocketdyne drawings and from information received from Rocketdyne via the NASA MSFC project manager. The Rocketdyne and the large-scale model seal clearances are tabulated in Figs. 3-7 and 3-8. The seal locations are also identified on Fig. 3-7. The large-scale model clearances were twice the mean SSME HPFTP (Phase II - full power level) clearances as determined by Rocketdyne. Deviations from the large-scale model nominal clearances were also measured at assembly.

3.2 Facility

The UTRC Internal Flow Systems Facility has mechanical drive systems, air and CO_2 gas supply system and instrumentation systems to conduct a range of disk/cavity and non-gas path flow experiments relating to turbomachinery.

The photograph (Fig. 3-9) shows the SSME Turbine Disk Model installed in the Facility test bed. The rotor assembly was driven by a 60 HP variable speed DC motor hidden at the left rear of the photograph. (The 30 HP motor shown at the right side of the photograph is used for two shaft experiments.) Flexible hosing shown over the model connects the model manifold system (Figs. 3-5 and 6) to the facilities Air Control and Air Measuring System (Fig. 3-10). Pneumatic tubing are shown near the center of the model and lead to the control room and to the CO_2 measuring instrumentation shown at the left in Fig. 3-10.

3.3 Instrumentation

The model was instrumented with thermocouples and pressure taps. The instrument locations are shown on Fig. 3-11. These instrumentation locations with radial location and identification numbers and letters will also be shown later in the discussion of the baseline flow condition. The pressure taps were used both to measure surface pressure and to withdraw samples of air with trace amounts of additional CO_2. The pressure measurements were conducted during the checkout phase of the experiments. When the flow condition was established, only a limited number of pressure measurements were obtained for each test to ensure that the simulated gas path pressures and flow conditions were maintained. The principal measurements obtained for each test were the CO_2 gas concentration measurements.

Data Acquisition and Control Unit - A Hewlett-Packard HP3497A and HP3498A data acquisition and control unit provides up to 300 analog channels for sampling output voltages

All dimensions in inches

a) Seal Clearances

Seal No.	SSME HPFTP Turbine (Phase II Full Power Level) Axial	Radial	Large-Scale Model Axial	Radial
1	0.019 +0.030	0.0410 +0.018(U)	0.039	0.082(U)
		0.0080 +0.003(L)		0.016(L)
2	-	0.0105 +0.003	-	0.021
3	0.058 +0.030	0.0730 +0.006(U)	0.0116	0.146(U)
		0.0130 +0.005(L)		0.025(L)
4	-	0.0100 +0.004	-	0.019
5	-	0.0050 +0.001	-	0.010

b) Seal Locations on Large Scale Model

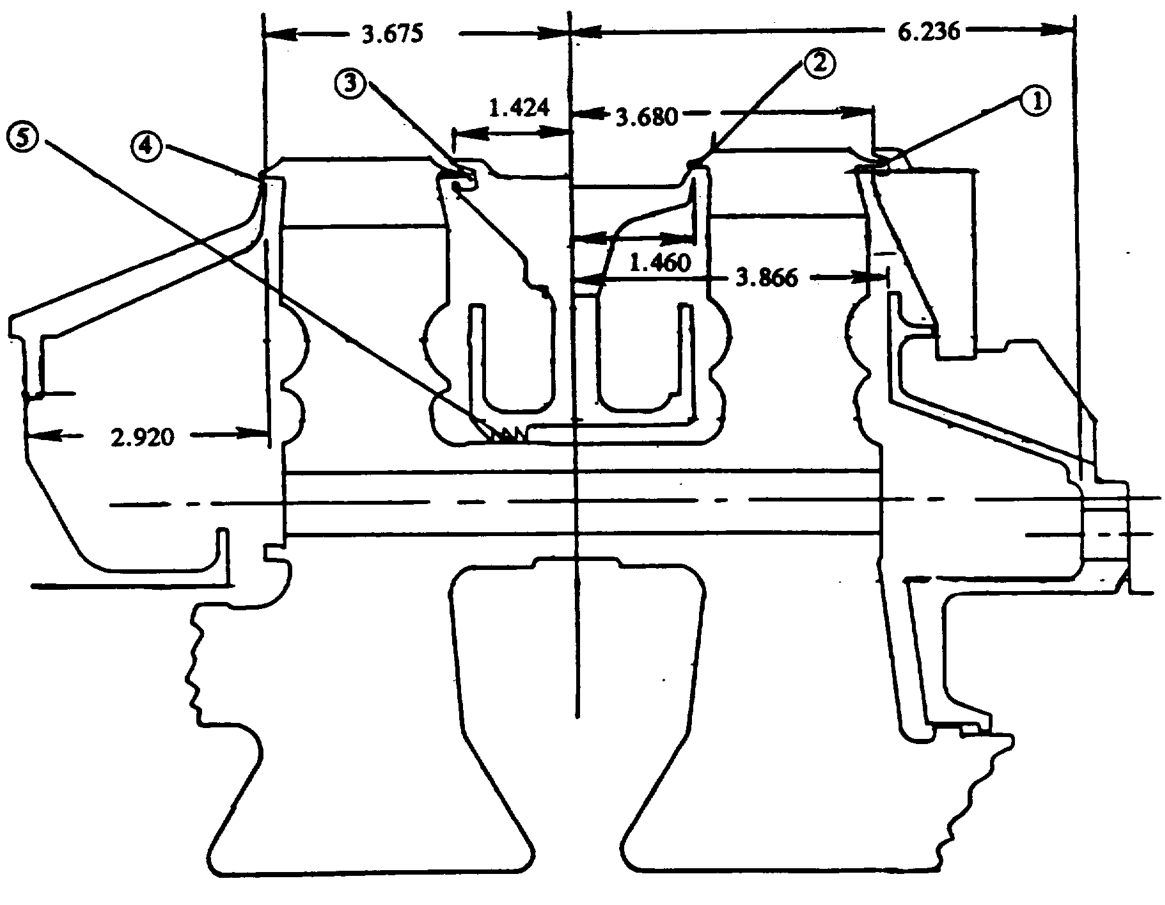


Figure 3-7. Clearances and Locations of Seals in SSME Fuel Turbine and Large-Scale Model

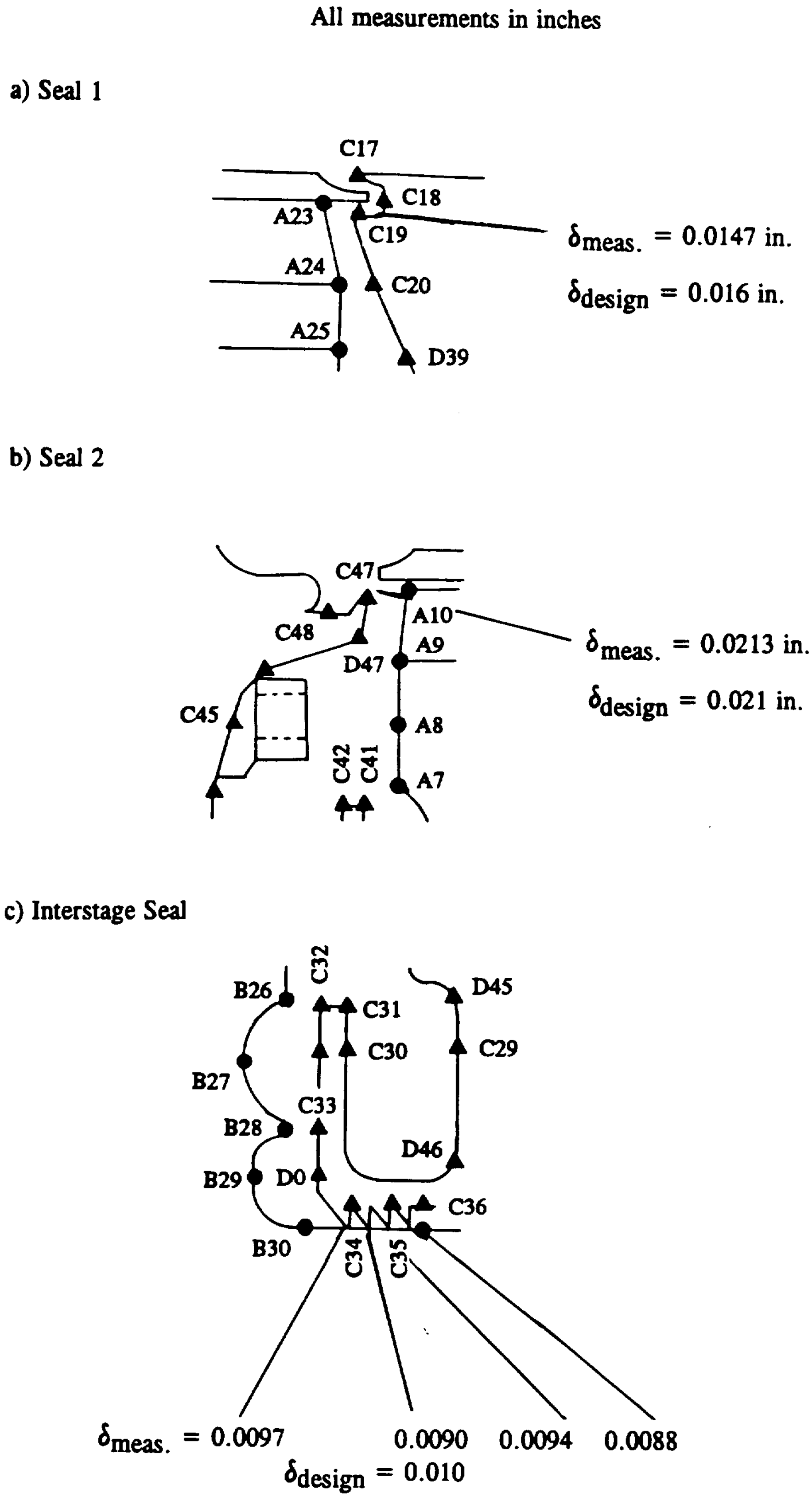


Figure 3-8. Results of Post-Test Seal Measurements

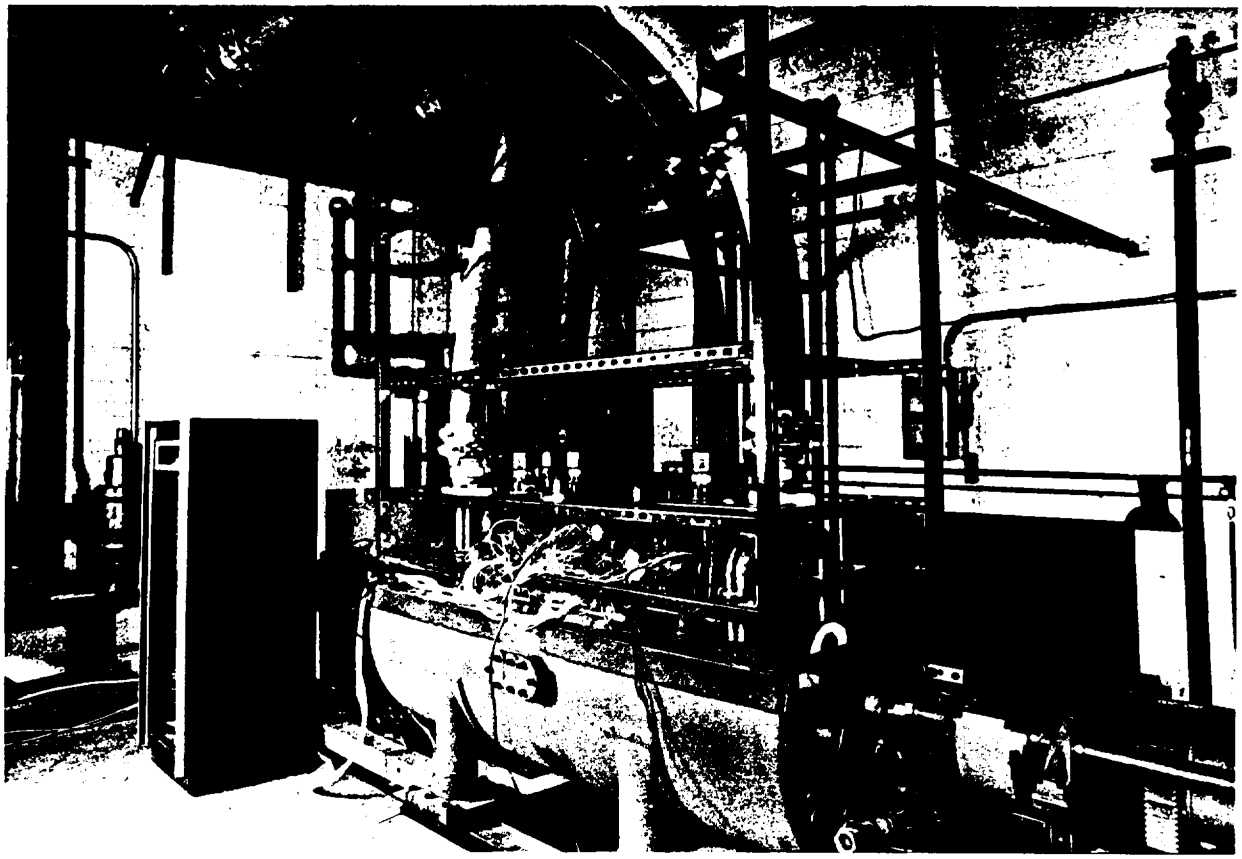


Figure 3-9. SSME Turbine Disk Cavity Model Installed in UTRC Internal Flow Systems Test Facility

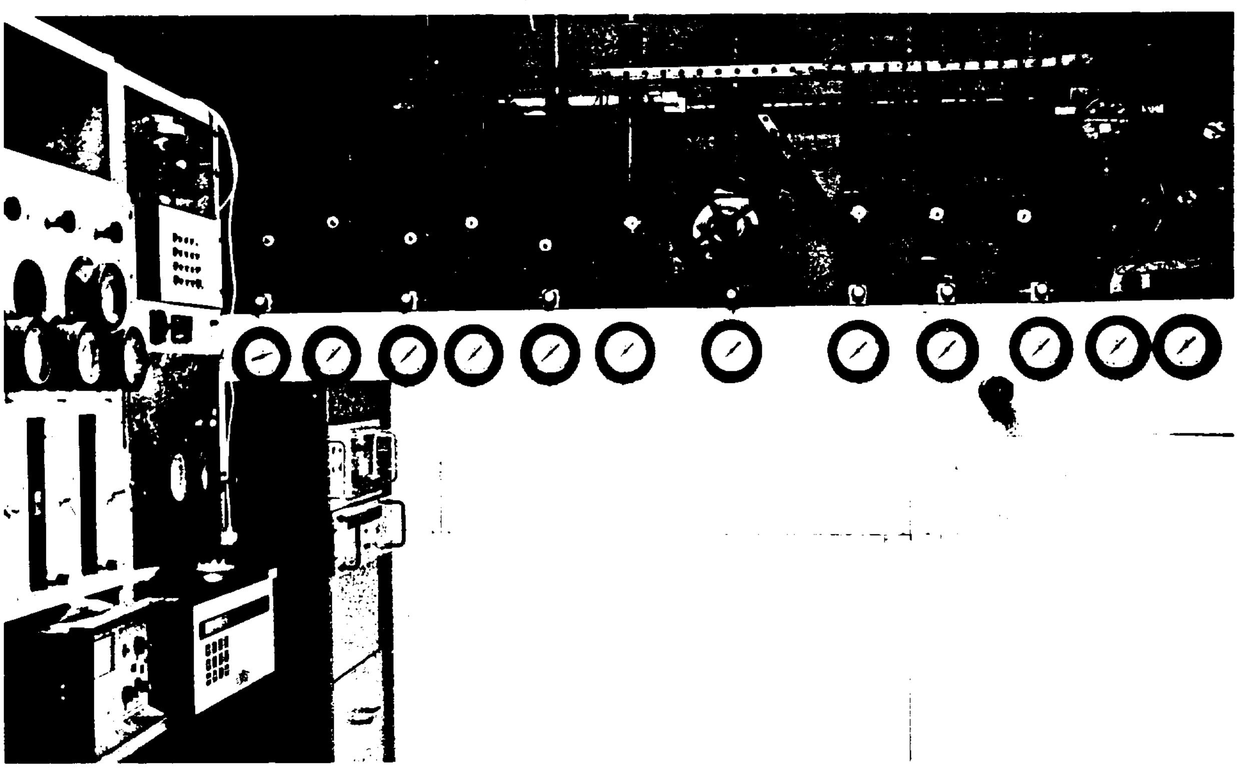


Figure 3-10. CO_2 Instrumentation, Air Control and Air Flow Measuring System of UTRC Internal Flow Systems Test Facility

□ Thermocouples (12)

○ Pressure/CO_2 taps in blade shaft passages (24)

● Pressure/CO_2 taps on rotating components (47)

▲ Pressure/CO_2 taps on stationary components (58)

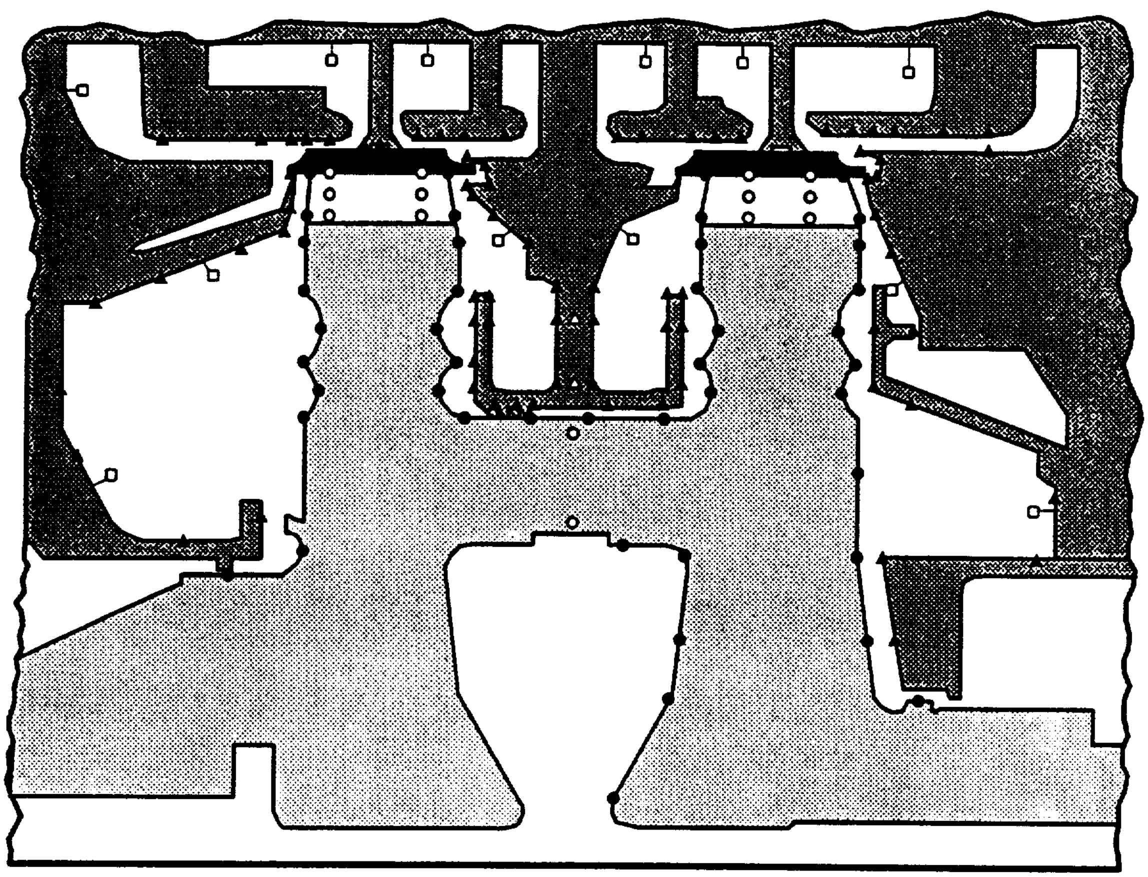


Figure 3-11. Instrumentation Locations on Large-Scale Model

from thermocouples, heat flux sensors, torque meters, strain gages, flowmeters, and pressure transducers. The unit is controlled manually (thereby simplifying checkout procedures) or by computer through an IEEE 488 interface. Sampling rates and channel selection can be varied and event timing can be recorded with the built-in clock.

Flow and Pressure Measuring Equipment - Four EFM turbine flowmeters and eleven orifice plate assemblies are used to measure flowrates to the facility and test models. The flowmeter output signal is sensed by a Hewlett-Packard HP5384A frequency meter which is computer controlled through an IEEE 488 interface. Pressure measurements in flow lines, test models, and test chamber are obtained with three Scanivalve Model 48J4-1 scanning valve assemblies. Two of the 48-port scanning valve assemblies are used for making pressure measurements in test models in the rotating reference frame. All three scanning valve assemblies are controlled manually or by computer through the HP3497A data acquisition and control unit. Pressure transducers are available in ranges of ±1 psid to ±250 psid.

Gas Sampling Equipment - A Beckman Non-Dispersive Infrared Model 865 Analyzer is used for measuring carbon dioxide concentrations for ingestion and mass transfer investigations. Measurements are obtained from a multiple number of ports by using 2 or 3 Scanivalve Model 48J4-1 scanning valve assemblies to direct the gas sample from a specific location on the model to the gas analyzer. The system is operated manually or by computer.

Vibration Sensors and Safety Circuits - Rig and test model vibration levels are sensed by numerous Vibramite Model 302-9 vibration sensors. The sensors are mounted in horizontal and vertical pairs on drive shaft spindles, test model supports, bearing blocks, and other load bearing structures. Vibration sensor outputs are monitored by several Pratt & Whitney (P&W) Model 1517-1 vibration monitors. The monitors are connected to the facility drive system control station and automatically shut off all systems when vibration levels exceed 2 mils at any sensor location.

Slipring Assembly - A Wendon Model W200-4-100 200 channel slipring assembly transmits transducer output and transducer excitation signals between the stationary and the rotating frames of reference.

Computers - An IBM PS 2/80 computer was used as the principal data acquisition computer for pressure and thermocouple data. The data acquisition programs used were adapted from previous UTRC data acquisition codes for the HP3497A data acquisition and control unit. An IBM PC together with an HP3497A unit were used to automate the CO_2 sampling process.

4.0 EXPERIMENTAL PARAMETERS AND TEST MATRIX

The objectives of this project was to determine the influence of the geometric and flow parameters on the flow and heat transfer in the disk cavities of rocket turbopumps. The geometric configuration selected for the study was the SSME High Pressure Fuel Turbo Pump (HPFTP). As previously noted, the Large Scale Model used for the experiments was two times the full scale pump. The rim seal clearances were scaled from drawings and information received via the NASA MSFC technical program management.

The flow conditions at the gas path rim for the SSME HPFTP are shown in Table 4–1. The rim Reynolds number, Re_t, are a factor of 10 greater than those obtainable for the test program. However, the UTRC test Reynolds numbers always exceeded 10^6 and therefore the results can be scaled using conventional dimensionless flow parameters for turbulent flow. Note that the reference Mach numbers of the full scale rocket flow at the rim condition are 0.27 and the absolute Mach number of the flows is less than 0.5. Thus, the gas path pressure drop across the stages can be scaled with reasonable accuracy using the dimensionless parameter, $(P_{ref}-P)/q_{ref}$. Although the model was designed for a maximum reference Mach number (in the simulated gas path) of 0.24 to 0.28, air supply limitations at UTRC during the periods preceding and during the tests limited the reference Mach number to approximately 0.17. This limitation does not adversely affect the usefulness of the results from the experiment due to the basically incompressible nature of the flow and the high Reynolds numbers, i.e. $\sim 10^6$.

An initial series of 12 experiments were conducted to set the Baseline Flow Conditions, using estimates of flow through each seal and through the three coolant supplies that were previously prepared based on early SSME HPFTP tests. The test conditions were scaled from estimates [Ref. 5] using the parameters shown in Table 4–1. After a series of efforts, it became apparent that the flow rates, estimated using Ref. 5, through the first and second seals, were incompatible with the rim seal clearances in the model and the gas path pressure drop between those seals. An analysis indicated that the running rim seal clearances and effective areas for the previous tests were approximately 50 percent larger than those for the present model. The conclusion from this analysis was that the gas path pressure distribution should be simulated using the $(P_{ref}-P)/q_{ref}$ parameter. The effects of the larger rim seal clearances on the flow characteristics in the cavities can be determined at a future date.

The dimensional and dimensionless flow conditions for the Baseline Flow Condition (Test 202) are shown in Table 4–2. Note that the $(P_{ref}-P)/q_{ref}$ parameter are approximately the same for Seals 1, 2 and 3 as estimated for the full scale turbopump. The gas path pressure, and hence pressure parameter, above Seal 4 was adjusted as required to balance the flow system.

The gas source experimental investigation of the SSME HPFTP turbopump turbine disk cavity aerodynamics and heat transfer was comprised of 35 tests. The test matrix for these tests was built around the SSME HPFTP Full Power Level (FPL) operating range of parameters. Table 4–1 presents values for the SSME HPFTP at FPL. The dimensional parameters are:

Ω	–	Rotation rate, rad/sec
P	–	Pressure, psia
T	–	Temperature, R

R_o – Reference radius, in.

V_o – Velocity of disk at R_o, ft/sec

V_ϕ – Gas path flow tangential velocity, ft/sec

V_z – Gas path flow axial velocity, ft/sec

The rim seal locations at which these conditions exist are indicated in Table 4–2. From these parameters, dimensionless parameters at each seal location were formed. These dimensionless parameters were used to scale the experiments in the Large Scale Model. These dimensionless parameters are as follows:

M_o – Mach number based on gas path tangential velocity

V_ϕ/V_o – Ratio of gas path tangential to disk velocity

V_z/V_o – Ratio of gas path axial to disk velocity

$(P_{ref}-P)/Q_{ref}$ – Dimensionless pressure drop across seal

Re_t – Tangential Reynolds number based on disk velocity

Re_η – Dimensionless seal flow parameter

$Re_\eta/Re^{0.8}$ – Flow parameter

Of the 35 tests performed, the first twenty–seven tests used air for both the gas path and disk cavity bleed flows. These tests were performed to determine a baseline for the constant density tests. For the constant density tests, the disk cavity cooling flow rates were varied and small amounts of trace gas (CO_2) were used to determine the local flow composition within the Large Scale Model. The test number, disk rotation rate and the dimensionless seal flow rates for these tests are shown in Table 4–3. All dimensional and dimensionless parameters for these tests can be found in tabulated form at the end of this report (Section 8). In these tabulations, the test conditions for a particular test number are presented in tabular form.

Of the 35 tests performed, the last eight tests were conducted using CO_2 as the coolant in the aft disk cavity. The test numbers, rotation rates and coolant flow rates for these tests are also presented in Table 4–3. These tests were conducted to determine the effect of coolant density on cavity flow distribution within the forward and aft disk cavities. As with the constant density tests, all dimensional and dimensionless parameters can be found in tabulated form (Section 8). These tests were conducted at one Reynolds number and only the coolant flow rate to the aft cavity was varied.

Each tabulated test data set consists of a table of test conditions followed by a table of gas source concentration measurements. The results for Test 202 shown in Table 4–4 are representative of this format. Referring to Table 4–4, the test conditions are given in dimensional and dimensionless form. The model locations corresponding to the test conditions presented are identified in Figs. 5–3 through 5–8. The measured parameters

Table 4-1. Flow Conditions for SSME HPFTP Phase II Operation at Full Power Level (FPL)

Seal No.	Dimensional Parameters							Dimensionless Parameters						
	Ω (RPM)	P (psia)	T (^oR)	Ro (in)	V_o (ft/sec)	V_ϕ (ft/sec)	V_z (ft/sec)	M_o	$\frac{V_\phi}{V_o}$	$\frac{V_z}{V_o}$	$\frac{(P_{ref}-P)}{q_{ref}}$ *	Re_t $x10^7$	Re_m $x10^5$	$\frac{Re_m}{Re_t^{0.8}}$ *
1	36644	4726	1674	4.56	1458	2161	950	0.271	1.48	0.65	0.00	3.6	-1.0	0.090
2	36644	4370	1651	4.56	1458	-212	915	0.273	-0.15	0.63	-1.32	3.4	-0.6	0.054
3	36644	3804	1605	4.51	1442	2207	828	0.274	1.53	0.57	-3.68	3.0	1.0	0.104
4	36644	3582	1589	4.51	1442	39	882	0.275	0.03	0.61	-4.57	2.9	1.1	0.118

Table 4-2. Flow Conditions for Large-Scale Model Operation at Baseline Conditions

Seal No.	Dimensional Parameters							Dimensionless Parameters						
	Ω (RPM)	P (psia)	T (^oR)	Ro (in)	V_o (ft/sec)	V_ϕ (ft/sec)	V_z (ft/sec)	M_o	$\frac{V_\phi}{V_o}$	$\frac{V_z}{V_o}$	$\frac{(P_{ref}-P)}{q_{ref}}$ *	Re_t $x10^6$	Re_m $x10^4$	$\frac{Re_m}{Re_t^{0.8}}$ *
1	1502	57.2	530	9.12	120	201	67	0.106	1.68	0.56	0.00	2.2	-0.4	0.031
2	1502	56.5	530	9.12	120	0	66	0.106	0.00	0.55	-1.69	2.2	-0.3	-0.023
3	1502	55.5	530	9.12	120	179	65	0.106	1.49	0.54	-3.90	2.2	0.4	0.038
4	1502	54.9	530	9.12	120	0	81	0.106	0.00	0.68	-5.15	2.2	0.5	0.040

Notes: 1. $Re_m > 0$ indicates flow outward through seal
2. * indicates scaling parameter

Table 4-3

Table of Flow Conditions for Concentration Measurement Tests

Test No.	Ω rpm	P psia	Re $\times 10^{-6}$	ϕ_{12}	ϕ_{13}	ϕ_{14}	Coolant (14)
101	1003	60.55	1.65	0.027	0.014	0.012	Air
102	1004	60.55	1.64	0.027	0.012	0.012	Air
103	1000	58.11	1.57	0.029	0.011	0.013	Air
104	1000	59.91	1.61	0.027	0.014	0.025	Air
105	1001	52.83	1.44	0.037	0.018	0.012	Air
201	1502	57.37	2.38	0.027	0.013	0.013	Air
202	1502	57.24	2.19	0.017	0.008	0.013	Air
203	1500	58.50	2.21	0.028	0.014	0.012	Air
204	1501	54.54	2.25	0.030	0.014	0.015	Air
205	1504	57.79	2.24	0.030	0.015	0.014	Air
206	1502	54.12	2.18	0.032	0.015	0.015	Air
210	1497	60.90	2.48	0.024	0.012	0.014	Air
211	1503	61.02	2.46	0.022	0.011	0.014	Air
212	1495	61.02	2.44	0.020	0.010	0.014	Air
213	1492	60.99	2.43	0.014	0.007	0.014	Air
214	1493	61.34	2.45	0.010	0.005	0.014	Air
220	1495	61.09	2.48	0.022	0.013	0.014	Air
221	1494	61.08	2.45	0.021	0.011	0.014	Air
222	1493	61.29	2.45	0.014	0.007	0.014	Air
223	1492	61.76	2.42	0.010	0.002	0.014	Air
224	1492	61.70	2.42	0.006	0.005	0.014	Air
225	1496	61.60	2.37	0.001	0.002	0.014	Air
231	1494	62.66	2.40	0.025	0.013	0.011	Air
232	1494	62.46	2.39	0.025	0.013	0.009	Air
233	1493	62.38	2.39	0.025	0.013	0.008	Air
234	1494	62.22	2.39	0.025	0.013	0.007	Air
235	1494	62.44	2.41	0.024	0.013	0.004	Air
241	1499	62.31	2.37	0.025	0.014	0.014	CO_2
243	1497	62.43	2.36	0.025	0.014	0.014	CO_2
244	1496	62.58	2.37	0.025	0.014	0.011	CO_2
245	1495	47.80	1.80	0.028	0.016	0.009	CO_2
246	1495	62.66	2.34	0.025	0.014	0.005	CO_2
247	1495	62.59	2.34	0.025	0.014	0.003	CO_2
248	1495	62.81	2.34	0.025	0.014	0.007	CO_2
249	1496	62.83	2.34	0.025	0.014	0.010	CO_2

presented in Table 4–4 are the rotation rate, Ω source inlet gas pressure and temperature, P and T, and the source flow rate, m. The gas source viscosity, μ_f, is calculated using Sutherland's model [Ref. 6]. The gas path axial and tangential velocity components are calculated using flowpath geometry, pressure, temperature, and flow rates. All dimensionless parameters are calculated from these quantities.

Following the table of test conditions, gas source concentration measurements made at the various measurement locations in the model are presented. The measurement locations in the model are identified in the instrumentation map shown in Fig. 3–11 and again in Figs. 5–3 through 5–8. These instrumentation maps give the radial coordinates of each test port and identify the model component (A, B, C) where the data was acquired.

Referring to Table 4–4, the gas source concentration measurements, ϕ_i, are given for each location as a fraction, i, of the total flow at that location from the various gas sources, i. The gas source and exit locations, i, are given in Fig. 3–2. The column labeled TOTAL in Table 4–4 is the sum of all of the gas source concentration measurements at that location. For the most part, this sum is 1.00 +/–0.06 which indicates an overall concentration measurement accuracy of +/–6 percent. The gas concentration accuracy for each measurement was generally less than +/–0.03. However, the gas analyzers drifted during some tests such that negative concentration measurements and concentrations greater than 1.00 were recorded.

Table 4-4. Flow and Seal Test Parameters and Gas Source Concentrations for Baseline Flow Conditions (Test 202)

Parameter	Seal 1	Seal 2	Seal 3	Seal 4	Forward	Inner	Aft
	LOCATION						
Ω, Rpm	1502	1502	1502	1502	1502	1502	1502
P, psia	57.24	56.48	55.49	54.93	55.89	56.03	55.93
T, °R	530	530	530	530	530	530	532
Rho, lb/(ft^3)	0.292	0.288	0.283	0.280	0.284	0.285	0.284
Emdot, lb/sec	-0.224	-0.154	0.257	0.271	0.115	0.057	0.087
μ, lb/(ft sec)	1.21E-05	1.21E-05	1.21E-05	1.21E-05	1.21E-05	1.21E-05	1.21E-05
Ro, in	9.12	9.12	9.12	9.12	9.12	9.12	9.12
Vo, ft/sec	119.518	119.518	119.518	119.518	119.518	119.518	119.518
Vφ, ft/sec	200.943	0	178.610	0	-	-	-
Vz, ft/sec	67.019	65.629	64.823	81.149	-	-	-
Qo, psi	0.449	0.449	0.449	0.449	0.449	0.449	0.449
δp/q	0	-1.691	-3.908	-5.149	-3.007	-2.697	-2.916
Vφ/Vo	1.681	0	1.494	0	-	-	-
Vz/Vo	0.561	0.549	0.542	0.679	-	-	-
Reto	2.19E+06	2.19E+06	2.19E+06	2.19E+06	2.19E+06	2.19E+06	2.19E+06
Rer	-3660	-2659	4444	4692	1984	994	1495
Rer/(Ret^0.8)	-0.031	-0.023	0.038	0.040	0.017	0.008	0.013
Mφ	0.178	0	0.158	0	-	-	-
Coolant Gas	-	-	-	-	Air	Air	Air

GAS SOURCE CONCENTRATION

TEST	-	PORT	φ12	φ13	φ14	φ01	φ03	φ05	φ07	TOTAL
202	A	1	0.02	0.99	0.00	0.00	0.00	-	-	1.01
		2	0.00	1.00	0.00	0.00	0.00	-	-	1.01
		3	0.02	0.94	0.00	0.03	0.02	-	-	1.01
		4	0.03	0.90	0.01	0.04	0.04	-	-	1.02
		5	0.03	0.90	0.01	0.05	0.04	-	-	1.02
		6	0.04	0.87	0.01	0.06	0.05	-	-	1.02
		7	0.05	0.86	0.01	0.07	0.06	-	-	1.04
		8	0.09	0.67	0.01	0.13	0.11	-	-	1.01
		9	0.14	0.45	0.01	0.22	0.17	-	-	0.98
		10	0.07	0.01	0.01	0.11	0.79	-	-	0.99
		11	-	-	-	-	-	-	-	-
		12	0.42	0.03	0.01	0.55	0.01	-	-	1.01
		13	0.45	0.02	0.01	0.54	-0.00	-	-	1.02
		14	0.37	0.02	0.01	0.63	-0.01	-	-	1.02
		15	0.38	0.02	0.01	0.60	-0.01	-	-	1.00
		16	0.42	0.02	0.01	0.58	-0.02	-	-	1.01
		17	0.43	0.02	0.02	0.54	-0.03	-	-	0.98
		18	0.34	0.02	0.02	0.64	-0.04	-	-	0.99
		19	-	-	-	-	-	-	-	-
		20	0.41	0.02	0.02	0.57	-0.04	-	-	0.99
		21	0.64	0.02	0.02	0.37	-0.04	-	-	1.01
		22	0.75	0.02	0.02	0.25	-0.05	-	-	1.00
		23	0.09	0.02	0.02	0.93	-0.05	-	-	1.01
		24	0.96	0.02	0.02	0.09	-0.05	-	-	1.04
		25	1.05	0.02	0.02	0.01	-0.05	-	-	1.05
		26	1.05	0.03	0.02	0.01	-0.06	-	-	1.05
		27	1.06	0.02	0.02	0.01	-0.06	-	-	1.05
		28	0.98	0.02	0.02	0.01	-0.06	-	-	0.96
		29	0.97	0.02	0.02	0.01	-0.06	-	-	0.96
		30	0.98	0.02	0.02	0.01	-0.06	-	-	0.97
		31	0.99	0.02	0.02	0.01	-0.06	-	-	0.98
		32	0.99	0.02	0.02	0.01	-0.06	-	-	0.98
		33	1.00	0.02	0.02	0.01	-0.06	-	-	0.99
		34	0.02	0.95	0.02	0.01	-0.06	-	-	0.94
		35	0.01	0.96	0.02	0.01	-0.06	-	-	0.94
		36	0.01	0.96	0.02	0.01	-0.06	-	-	0.95
		37	0.01	0.97	0.03	0.01	-0.06	-	-	0.96
		38	0.01	0.97	0.03	0.01	-0.05	-	-	0.96
		39	0.01	0.98	0.03	0.01	-0.05	-	-	0.97
	B	1	0.01	0.01	1.00	0.01	0.01	-	-	1.05
		2	0.01	0.01	1.00	0.01	0.02	-	-	1.05
		3	0.01	0.01	0.99	0.02	0.02	-	-	1.05
		4	0.01	0.01	0.98	0.02	0.02	-	-	1.04

GAS SOURCE CONCENTRATION (Cont.)

TEST	-	PORT	ϕ12	ϕ13	ϕ14	ϕ01	ϕ03	ϕ05	ϕ07	TOTAL
202	B	5	0.01	0.02	0.99	0.02	0.02	-	-	1.06
		6	0.01	0.02	0.99	0.02	0.02	-	-	1.06
		7	0.01	0.02	0.98	0.02	0.02	-	-	1.06
		8	0.02	0.02	0.98	0.02	0.02	-	-	1.06
		9	0.02	0.02	0.98	0.02	0.02	-	-	1.06
		10	0.21	0.12	0.06	0.34	0.30	-	-	1.03
		11	0.21	0.12	0.06	0.33	0.29	-	-	1.01
		12	0.22	0.13	0.02	0.33	0.30	-	-	1.01
		13	0.23	0.13	0.02	0.35	0.29	-	-	1.01
		14	0.23	0.13	0.02	0.35	0.30	-	-	1.02
		15	0.23	0.13	0.02	0.33	0.29	-	-	1.00
		16	0.23	0.13	0.02	0.35	0.28	-	-	1.01
		17	0.23	0.13	0.02	0.34	0.28	-	-	1.00
		18	0.23	0.13	0.02	0.34	0.27	-	-	1.00
		19	0.23	0.13	0.02	0.34	0.27	-	-	0.99
		20	0.23	0.13	0.02	0.34	0.27	-	-	0.99
		21	0.23	0.13	0.02	0.34	0.26	-	-	0.99
		22	0.22	0.21	0.03	0.30	0.23	-	-	0.98
		23	0.24	0.12	0.03	0.33	0.26	-	-	0.98
		24	0.23	0.14	0.03	0.34	0.25	-	-	0.99
		25	0.23	0.17	0.03	0.29	0.23	-	-	0.95
		26	0.22	0.22	0.03	0.29	0.22	-	-	0.97
		27	0.18	0.26	0.03	0.29	0.20	-	-	0.95
		28	0.17	0.31	0.03	0.27	0.18	-	-	0.96
		29	0.18	0.32	0.03	0.25	0.18	-	-	0.95
		30	0.06	0.77	0.03	0.08	0.01	-	-	0.95
	C	1	0.00	0.01	0.00	1.01	0.01	-	-	1.03
		2	0.00	0.01	0.01	0.01	0.99	-	-	1.01
		3	0.00	0.01	0.01	0.00	0.01	-	-	0.02
		4	0.00	0.01	0.01	0.00	0.00	-	-	0.02
		5	1.03	0.01	0.01	0.00	0.00	-	-	1.06
		6	0.01	1.03	0.01	0.00	0.00	-	-	1.04
		7	0.01	0.01	0.99	0.00	0.01	-	-	1.01
		8	0.01	0.01	0.96	0.01	0.01	-	-	1.00
		9	0.01	0.01	0.95	0.01	0.01	-	-	1.00
		10	0.01	0.01	0.95	0.01	0.02	-	-	1.01
		11	0.05	0.03	0.77	0.07	0.07	-	-	0.99
		12	0.05	0.03	0.11	0.07	0.06	-	-	0.31
		13	0.02	0.02	0.01	0.02	0.01	-	-	0.08
		14	0.01	0.01	0.02	0.00	0.95	-	-	0.99
		15	0.01	0.01	0.02	1.02	-0.02	-	-	1.03
		16	0.01	0.01	0.02	1.01	-0.03	-	-	1.01
		17	0.01	0.01	0.02	0.99	-0.03	-	-	0.99
		18	0.01	0.01	0.02	0.99	-0.04	-	-	1.00
		19	0.01	0.01	0.02	1.00	-0.04	-	-	1.00
		20	0.73	0.01	0.02	0.28	-0.04	-	-	1.00
		21	1.01	0.02	0.02	0.04	-0.04	-	-	1.03
		22	1.02	0.02	0.02	0.02	-0.05	-	-	1.03
		23	1.04	0.02	0.02	0.01	-0.05	-	-	1.03
		24	1.05	0.02	0.02	0.01	-0.05	-	-	1.04
		25	0.24	0.11	0.02	0.33	0.25	-	-	0.96
		26	0.25	0.12	0.02	0.35	0.24	-	-	0.98
		27	0.23	0.12	0.02	0.34	0.24	-	-	0.96
		28	0.97	0.11	0.02	0.37	0.24	-	-	1.71
		29	0.23	0.11	0.02	0.33	0.25	-	-	0.95
		30	0.23	0.11	0.02	0.34	0.25	-	-	0.95
		31	0.23	0.11	0.03	0.33	0.25	-	-	0.95
		32	0.21	0.16	0.03	0.32	0.23	-	-	0.96
		33	0.21	0.19	0.03	0.31	0.23	-	-	0.96
		34	0.02	0.94	0.03	0.02	-0.05	-	-	0.96
		35	0.02	0.93	0.03	0.02	-0.05	-	-	0.94
		36	0.02	0.94	0.03	0.02	-0.05	-	-	0.95
		37	0.02	0.94	0.03	0.02	-0.04	-	-	0.95
		38	0.02	0.93	0.03	0.01	-0.04	-	-	0.95
		39	0.07	0.71	0.03	0.10	0.04	-	-	0.95
		40	0.09	0.67	0.03	0.12	0.06	-	-	0.96
		41	0.15	0.43	0.03	0.21	0.14	-	-	0.95
		42	0.22	0.18	0.03	0.31	0.22	-	-	0.96
		43	0.23	0.14	0.03	0.34	0.24	-	-	0.98
		44	0.24	0.12	0.03	0.32	0.28	-	-	0.98
		45	0.24	0.08	0.03	0.39	0.26	-	-	0.99
		46	0.23	0.08	0.03	0.39	0.25	-	-	0.99
		47	0.01	0.03	0.03	0.03	0.88	-	-	0.99
		48	0.01	0.03	0.03	0.04	0.89	-	-	0.99

5.0 EXPERIMENTAL RESULTS

The discussion of the test results will focus on one section of the model at a time. These sections are defined as REGION I, II, III, IV, V, and VI and are shown in Fig. 5–1. Region I consists of the forward coolant cavity and the upstream face of the first stage rotor. Region II consists of the center coolant cavity and the downstream face of the first stage rotor. Region III consists of the center coolant cavity and the upstream face of the second stage rotor. Region IV consists of the aft coolant cavity and the downstream side of the second stage rotor. The first and second rotor blade shank models comprise Regions VI and V, respectively. The gas source and sink locations, numbered 1 through 14, previously presented in Fig. 3–2, are also shown in Fig. 5–1.

The discussion of the experimental results will revolve around a baseline case for which air was used as the model coolant in the forward, inner, and aft coolant cavities as well as in the main gas path flows. In general, the results for this baseline case are typical for all tests where air was used as the coolant. The effects of rotation rate, coolant flow rate, and geometry will be presented. Following a discussion of the results for the baseline case, the effects of coolant flow rate, coolant density and Reynolds number will be discussed.

5.1 Baseline Tests

Test 202 flow conditions were chosen as being typical of the baseline tests where air was used as the coolant in the forward, center and aft disk cavity models. These tests were conducted to determine the effects of rotation rate, coolant flow rate, and flow source on the fluid composition at various locations in the model. The flow conditions for Test 202 are shown in Table 4–4. The rotation rate for this test was 1502 Rpm and the main gas path model inlet pressure and temperature were adjusted to attain a tangential Reynolds number, Ret, of approximately 2.2×10^6. The main gas path Mach number, based on the gas path tangential velocity component, was 0.178. The results for this flow condition in each of the model regions are presented in Table 4–4. The discussion of the results for this baseline case follows.

Region I

The main coolant source for this region is source location 12 at the cavity ID (Fig. 5–1). This coolant source models the coolant flow from the front bearing compartment of the SSME High Pressure Fuel Turbopump. The gas concentration measurements made in this region are presented in Fig. 5–2. The results indicate that at all radii below that of the blade shank region (below ports A24 and C20), the gas source is primarily from the coolant flow at the ID of the cavity (location 12). Above this radius, the fluid composition is a combination of the coolant flow and the flow which is ingested from the gas path through the upstream rim seal. The results for location C20 indicate that the fluid at this point is comprised of approximately 73 percent coolant flow and approximately 28 percent main gas path flow. These results show that mixing of the fluid ingested from the main gas path with that of the coolant from the cavity ID occurs only at the outer portion of the upstream face of the rotor and the forward stationary wall of the front cavity. This is probably due to the high flow rate of the coolant which is sufficient enough to prevent a large amount of flow recirculation in the front disk cavity. That is, the coolant flow rate is sufficient enough to supply the boundary-layer entrainment requirements on the rotor. A discussion of the effects of coolant flow rate on the fluid composition at the different radii in Region I will be presented later.

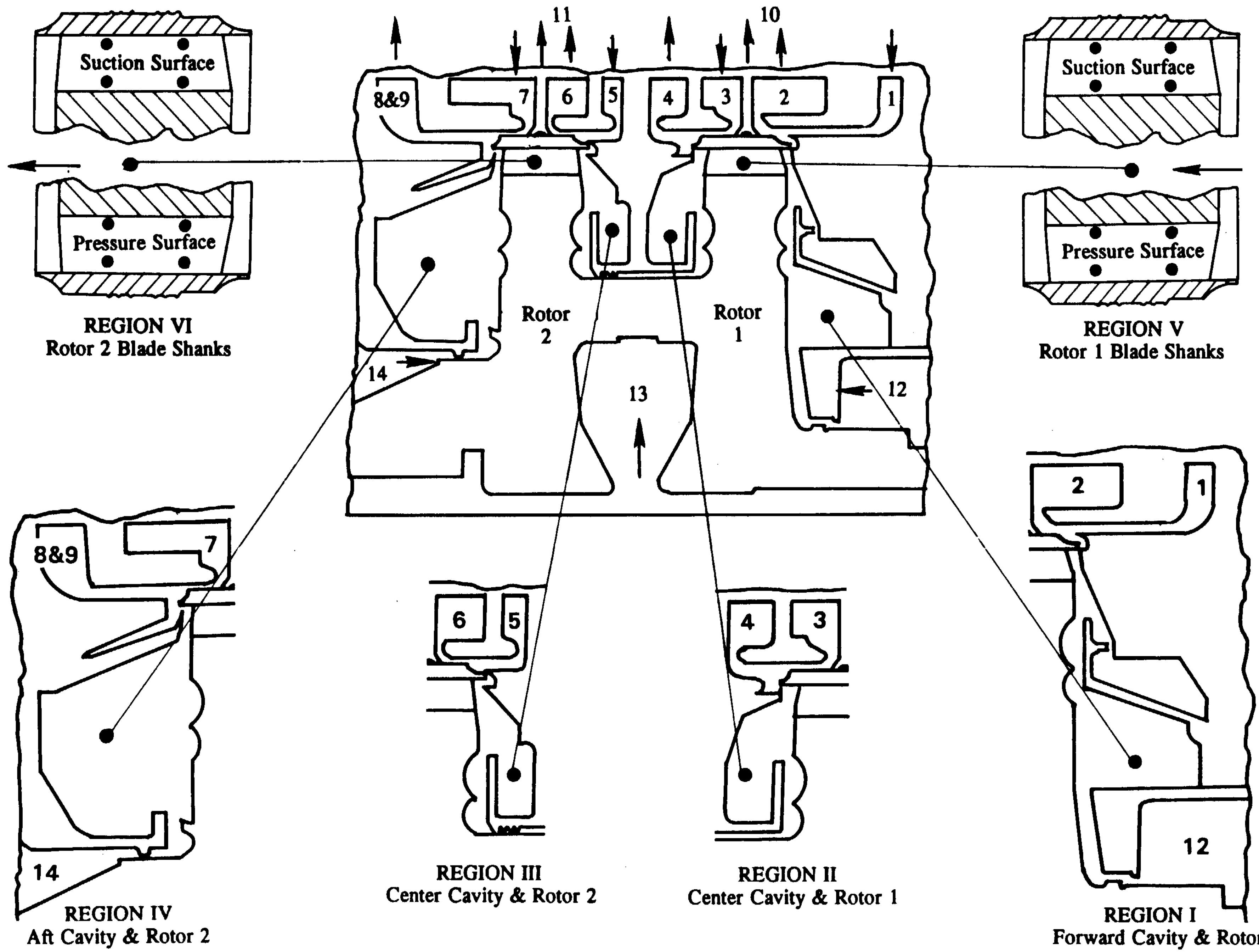
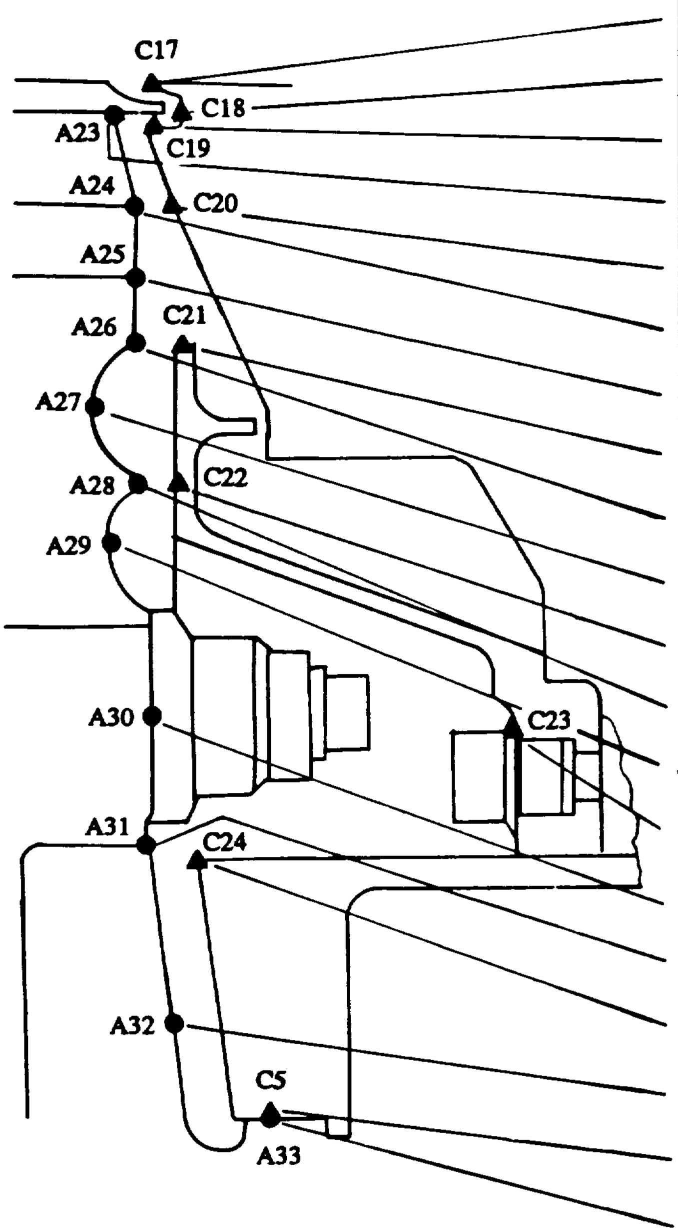


Figure 5-1. Model Seal Region and Gas Source/Exit Locations

REGION I - Forward Cavity and Rotor 1



LOC	RADIUS	ϕ_{12}	ϕ_{13}	ϕ_{14}	ϕ_{01}	ϕ_{03}
C17	9.224	0.00	0.00	0.00	0.99	0.00
C18	9.056	0.00	0.00	0.00	0.99	0.00
C19	9.008	0.00	0.00	0.00	1.00	0.00
A23	9.008	0.09	0.00	0.00	0.93	0.00
C20	8.375	0.73	0.00	0.00	0.28	0.00
A24	8.378	0.96	0.00	0.00	0.09	0.00
A25	7.875	1.05	0.00	0.02	0.00	0.00
C21	7.460	1.00	0.00	0.00	0.04	0.00
A26	7.530	1.05	0.03	0.02	0.00	0.00
A27	7.050	1.06	0.00	0.02	0.00	0.00
C22	6.460	1.02	0.00	0.00	0.00	0.00
A28	6.550	0.98	0.00	0.02	0.00	0.00
A29	6.106	0.97	0.02	0.02	0.00	0.00
C23	5.210	1.04	0.00	0.00	0.00	0.00
A30	5.000	0.98	0.02	0.02	0.00	0.00
A31	2.940	0.99	0.00	0.02	0.00	0.00
C24	3.970	1.05	0.00	0.00	0.00	0.00
A32	3.940	0.99	0.00	0.02	0.00	0.00
C5	2.263	1.03	0.00	0.00	0.00	0.00
A33	2.248	1.00	0.00	0.02	0.00	0.00

Figure 5-2. Gas Source Measurement Results for Flow Condition 202 in Region I - Forward Cavity and Rotor 1

Note in Fig. 5-2 that the only sources of fluid in Region I are the front cavity coolant flow and the main gas path flow which is ingested through the first stage rim seal. The gas concentration measurements for flow contribution from the center and aft cavity coolant sources as well as the flow ingested through the first stage downstream seal (Seal 2, gas source 3) are all essentially zero. This indicates that the flow and mixing process in this region of the model involves only two flow sources.

Region II

Results for Test 202 flow conditions in Region II are presented in Fig. 5-3. The ID coolant source for this region is source location 13. This coolant flow enters the interstage region through coolant holes in the shaft where the first and second stage rotors are joined. This coolant flow models the flow from the center cavity of the SSME HPFTP.

Consider first the results for the ID cavity (the cavity between the disk bores) and the coolant passages in the rotor shaft (ports A35–A39 and A1). Results of the gas concentration measurements made here indicate that the fluid at these locations is solely from the coolant flow (flow source 13). The flow composition on the rotor shaft OD and the interstage seal ID (ports A2–A3 and C37) is comprised of the fluid from this coolant source. At higher radii the fluid composition on both rotating and stationary walls is comprised of several flow sources.

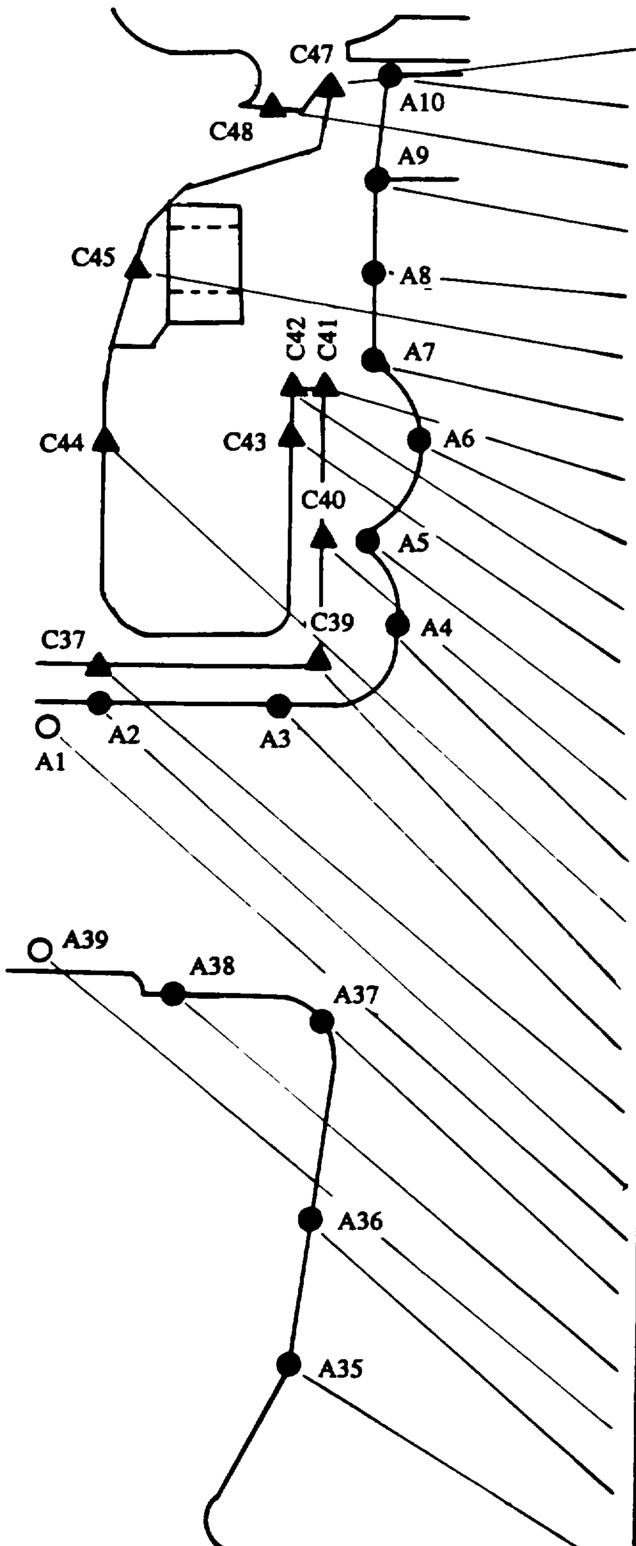
Examine the results shown in Fig. 5-3 for the port locations C39 and A4. The results at C39 on the corner of the "wing" on the stationary interstage seal indicate that the fluid here is made up of flow from several sources in approximately the following proportions: 71 percent from source 13, 10 percent from source 1, 7 percent from source 12, and 4 percent from source 3. The results at A4 on the rotor show compositions of 90 percent from source 13, 4 percent from source 1, 3 percent from source 12, and 4 percent from source 3. These results indicate that the coolant flow to the center cavity fills the area between the rotor shaft OD and the interstage seal ID and is then pumped radially outwards where it is mixed with (a) flow from the front cavity (Region I) which flows through the blade shanks and with (b) fluid which is ingested from the gas path through the overlap seal on the downstream side of the first stage rotor (source 13). This mixed flow is then recirculated and is entrained into the rotor and stator boundary layers. The concentration measurements at radii above A4 on the rotor indicate a larger fraction of the flow from source 13 then do measurements at corresponding radii on the interstage seal wall. The results at A7 for example show that 86 percent of the fluid there comes from source 13 while at C41, only 43 percent of the flow comes from this source.

Note the results in Fig. 5-3 for ports C44 and C45. The concentration measurements here indicate that only a small fraction of the flow at these locations comes from coolant entering the region through the rotor shaft. In fact, more flow from the front cavity coolant source (source 12) reaches these locations than does that from the center source (source 13). This indicates that the coolant from the center cavity has a small influence on the heat transfer characteristics in this area. Perhaps removal of the interstage seal "wing" would lead to a more enhanced mixing process in Region II if enhanced mixing is desirable in this region.

Region III

Results for Test 202 flow conditions in Region III are presented in Fig. 5-4. Consider the results shown in Fig. 5-4 at the interstage labyrinth seal (ports C34–C36). All of the flow

REGION II - Center Cavity & Rotor 1



LOC	RADIUS	ϕ_{12}	ϕ_{13}	ϕ_{14}	ϕ_{01}	ϕ_{03}
C47	8.989	0.00	0.03	0.03	0.03	0.88
A10	9.008	0.07	0.00	0.00	0.11	0.79
C48	8.810	0.00	0.03	0.03	0.04	0.89
A9	8.378	0.14	0.45	0.00	0.22	0.17
A8	7.768	0.09	0.67	0.00	0.13	0.11
C45	8.200	0.24	0.08	0.03	0.39	0.26
A7	7.560	0.05	0.86	0.00	0.07	0.06
C41	7.280	0.14	0.43	0.03	0.21	0.14
A6	7.050	0.04	0.87	0.00	0.06	0.05
C42	7.280	0.22	0.18	0.03	0.31	0.22
C43	6.900	0.23	0.14	0.03	0.34	0.24
A5	6.562	0.03	0.90	0.00	0.05	0.04
C40	6.340	0.08	0.67	0.03	0.12	0.06
A4	6.125	0.03	0.90	0.00	0.04	0.04
C44	6.900	0.24	0.12	0.03	0.32	0.28
C39	6.060	0.07	0.71	0.03	0.10	0.04
A3	5.700	0.00	0.94	0.00	0.02	0.02
C37	5.900	0.00	0.94	0.03	0.00	0.00
A2	5.700	0.00	1.00	0.00	0.00	0.00
A1	5.543	0.02	0.99	0.00	0.00	0.00
A37	4.026	0.00	0.97	0.02	0.00	0.00
A38	4.120	0.00	0.97	0.02	0.00	0.00
A39	4.389	0.00	0.98	0.03	0.00	0.00
A36	3.100	0.00	0.96	0.02	0.00	0.00
A35	2.362	0.00	0.96	0.02	0.00	0.00

Figure 5-3. Gas Source Measurement Results for Flow Condition 202 in Region II - Center Cavity and Rotor 1

at these locations comes from the center coolant flow source (source 13). This is not surprising since the labyrinth seal was designed to direct the center coolant flow forward into Region II. Examination of the results on the rotor shaft OD and the upstream face of the second stage rotor bear this out. The concentrations at B30 for example show that only 77 percent of the fluid at this location comes from source 13 while the rest comes from sources 1, 3 and 12. This fraction of coolant flow is reduced by approximately 60 percent at the next outward radial measurement location (B29) on rotor 2. Here, the fraction of the flow from source 13 is only 32 percent (Compare this result with those of Fig. 5-3 for ports A2 and A3 at approximately the same radial location).

Although a smaller amount of the center cavity coolant flow (source 13) is distributed to Region III (due to the labyrinth seal) compared to Region II, there appears to be some similarity in the mixing process. The results of the disk and interstage seal wall concentration measurements indicate that the coolant flow from the center cavity through the labyrinth seal is pumped radially outwards and is mixed with flow coming from Region II. It must be remembered that some of the flow from Region II contains fluid from the center source (13). Examination of the results at C28–C31 reveals that this flow is comprised of approximately 10 percent of fluid from this source (13). The results from C32–C33 indicate however that the fluid from source 12 is on the order of 20 percent or twice that of the flow from source 13 at C28–C31.

Note from Fig. 5-4 that for the most part, the major contribution to the flow in the upper radii of Region III come from the flow ingested from the gas path through the first stage rotor seals (source 1). The distribution of flow from these sources in the upper radii of Region III are roughly 25 percent from the first rotor downstream seal (source 3) and 35 percent from the first rotor upstream seal (source 1). This means that approximately 60 percent of the fluid in this region comes from the main gas path. Local metal temperature gradients could be extremely high at locations such as blade platforms (B23) and blade attachments (B24) which are near the gas path temperature.

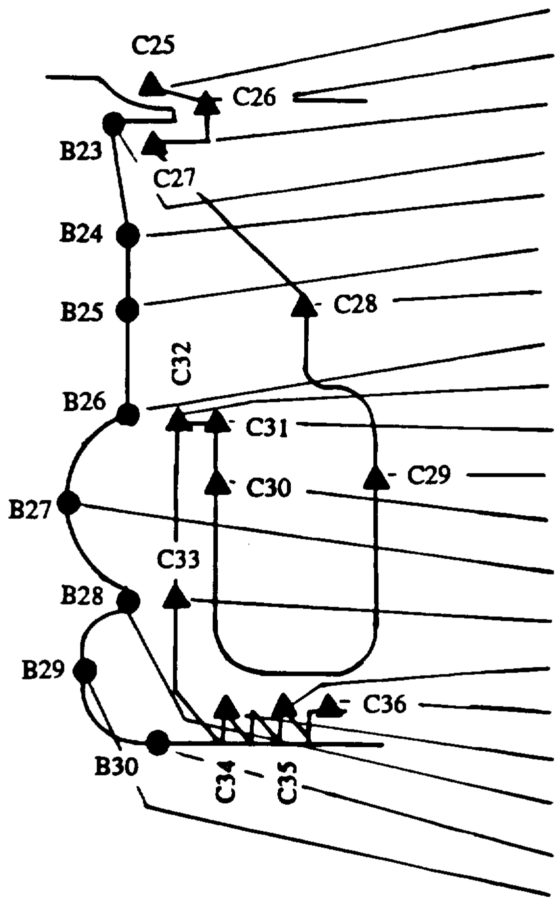
Region IV

Region IV results for Test 202 conditions are presented in Fig. 5- 5. The coolant source location for this region is source 14 as shown in Figs. 3-2 and 5-1. This coolant flow models the SSME HPFTP coolant flow through the aft ID labryinth seal from the fuel pump. Results shown in Fig. 5-5 indicate that at all radial locations up to the blade attachment area (B9) on both the rotor and the stator wall, the fluid composition is primarily that of the coolant source (source 14). Note at B9 on the rotor that the fluid is comprised of approximately 0.98 percent coolant flow. This finding indicates that there is very little mixing of the coolant and gas path fluid in this region when the coolant and gas path fluid densities are the same. Note the results for B9 and B10. The composition of the fluid at B9 is primarily "cold" coolant flow (0.98) while that at B10 is primarily (0.64 = 0.30 + 0.34) "hot" gas path fluid from sources 1 and 3. This may indicate that an extremely high thermal gradient could exist in the blade attachment and blade platform area of the second rotor.

Region V

Region V models the blade shank passage area on the first stage rotor. The results for Test 202 in this region are presented in Fig. 5-6. The results indicate that the fluid in the blade shank passages of the first rotor is made up of front cavity coolant (source 12) and gas path fluid (source 1) which has been ingested through the front cavity rim seal. Approximately 60

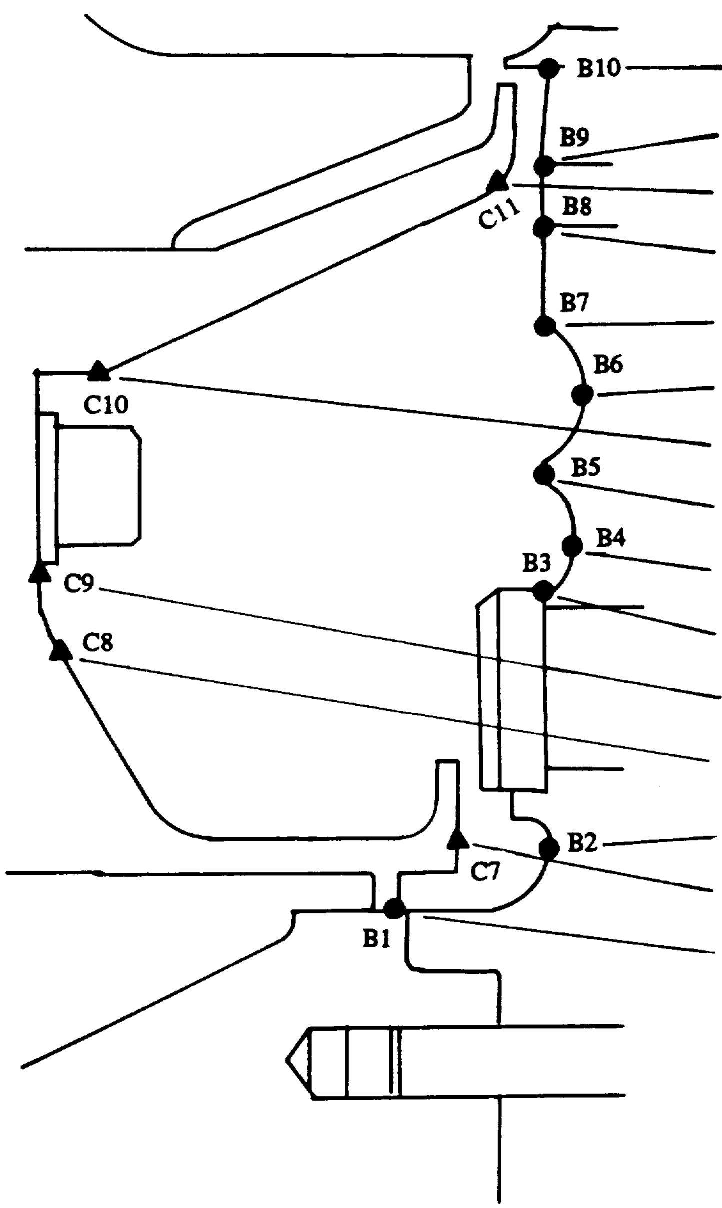
REGION III - Center Cavity & Rotor 2



LOC	RADIUS	φ_{12}	φ_{13}	φ_{14}	φ_{01}	φ_{03}
C25	9.140	0.24	0.11	0.02	0.33	0.25
C26	8.828	0.25	0.12	0.02	0.35	0.24
C27	8.830	0.23	0.12	0.02	0.34	0.24
B23	8.876	0.24	0.12	0.03	0.33	0.26
B24	8.237	0.23	0.14	0.03	0.34	0.25
B25	7.860	0.23	0.17	0.03	0.29	0.23
C28	8.570	XX	0.11	0.02	0.37	0.24
B26	7.520	0.22	0.22	0.03	0.29	0.22
C32	7.280	0.21	0.16	0.03	0.32	0.23
C31	7.280	0.23	0.11	0.03	0.33	0.25
C29	6.900	0.23	0.11	0.02	0.33	0.25
C30	6.900	0.23	0.11	0.02	0.34	0.25
B27	6.949	0.18	0.26	0.03	0.29	0.20
C33	6.340	0.20	0.19	0.03	0.31	0.23
C35	5.880	0.00	0.93	0.03	0.00	0.00
C36	5.900	0.00	0.94	0.03	0.00	0.00
C34	5.880	0.00	0.94	0.03	0.00	0.00
B28	6.442	0.17	0.31	0.03	0.27	0.18
B30	5.710	0.06	0.77	0.03	0.08	0.00
B29	6.000	0.18	0.32	0.03	0.25	0.18

Figure 5-4. Gas Source Measurement Results for Flow Condition 202 in Region III - Center Cavity and Rotor 2

REGION IV - Aft Cavity & Rotor 2



LOC	RADIUS	ϕ_{12}	ϕ_{13}	ϕ_{14}	ϕ_{01}	ϕ_{03}
B10	8.876	0.21	0.12	0.06	0.34	0.30
B9	8.237	0.00	0.00	0.98	0.00	0.00
C11	8.440	0.05	0.03	0.77	0.07	0.07
B8	7.875	0.00	0.00	0.98	0.00	0.00
B7	7.434	0.00	0.00	0.98	0.00	0.00
B6	6.950	0.00	0.00	0.99	0.00	0.00
C10	7.071	0.00	0.00	0.95	0.00	0.00
B5	6.440	0.00	0.00	0.99	0.00	0.00
B4	6.062	0.00	0.00	0.98	0.00	0.00
B3	5.665	0.00	0.00	0.98	0.00	0.00
C9	5.940	0.00	0.00	0.95	0.00	0.00
C8	5.250	0.00	0.00	0.96	0.00	0.00
B2	4.062	0.00	0.00	1.00	0.00	0.00
C7	4.312	0.00	0.00	0.99	0.00	0.00
B1	3.750	0.00	0.00	1.00	0.00	0.00

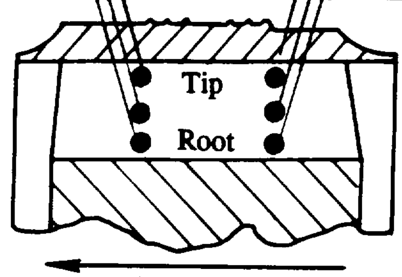
Figure 5-5. Gas Source Measurement Results for Flow Condition 202 in Region IV - Aft Cavity and Rotor 2

REGION V - Rotor 1 Blade Shanks

S - Suction Surface

LOC	ϕ_{12}	ϕ_{13}	ϕ_{14}	ϕ_{01}	ϕ_{03}
A13	0.45	0.00	0.00	0.54	0.00
A12	0.42	0.03	0.00	0.55	0.00
A11	–	–	–	–	–

LOC	ϕ_{12}	ϕ_{13}	ϕ_{14}	ϕ_{01}	ϕ_{03}
A22	0.41	0.00	0.00	0.57	0.00
A21	0.64	0.00	0.00	0.37	0.00
A20	0.75	0.00	0.00	0.25	0.00

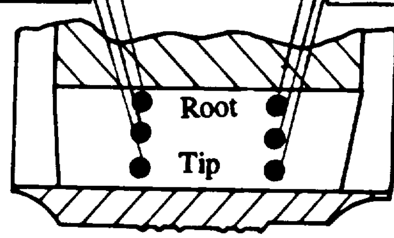


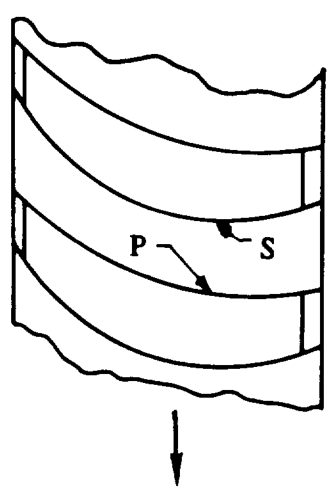
Direction of Flow

P - Pressure Surface

LOC	ϕ_{12}	ϕ_{13}	ϕ_{14}	ϕ_{01}	ϕ_{03}
A16	0.42	0.00	0.00	0.58	0.00
A15	0.38	0.00	0.00	0.61	0.00
A14	0.37	0.00	0.00	0.63	0.00

LOC	ϕ_{12}	ϕ_{13}	ϕ_{14}	ϕ_{01}	ϕ_{03}
A17	0.43	0.00	0.00	0.54	0.00
A18	0.34	0.02	0.00	0.64	0.00
A19	–	–	–	–	–





Direction of Rotation

Figure 5-6. Gas Source Measurement Results for Flow Condition 202 in Region V - Rotor 1 Blade Shanks

percent of the rotor passage fluid is gas path fluid. This is not surprising since the ingested gas path flow is approximately 60 percent of the total flow entering the front cavity.

Region VI

Region VI models the blade shank passage area on the second stage rotor. The results for Test 202 in this region are presented in Fig. 5- 7. The results indicate that the fluid in this region is comprised of front cavity coolant (source 12), center cavity coolant (source 13), and gas path fluid which has been ingested through the rim seals on both sides of rotor 1 (source 1 and source 3). The proportions of each of these fluid sources to the total flow in this area are approximately 23 percent from the front cavity coolant, 13 percent from the center cavity coolant, 33 percent gas path fluid ingested through the front rim seal and approximately 31 percent from the gas path through the first rotor downstream rim seal.

5.2 Effects of Coolant Flow Rate

To determine the affects of coolant flow rate on the cavity mixing process for the baseline tests in which air was used as the coolant, the coolant flow rate in the front and rear cavities was varied. The results for the aft cavity are shown in Fig. 5–8. Here, the measured concentrations of fluid from source 14 are plotted versus the non-dimensional coolant flow rate. Results are presented for five radial locations on the stationary and the rotating walls. Consider first the results shown in Fig. 5–8 for the rotor. The rotor concentration measurements indicate that for the most part, the fluid next to the rotor is primarily composed of fluid from the coolant source (source 14). Note that the measured rotor coolant concentrations fall below 80 percent at the higher radii only at the smallest coolant flow rate investigated. This indicates that the coolant concentration on the rotor surface remains high even at coolant flow rates which are approximately 1/4 of the design flow rate.

The measured coolant concentrations on the stationary wall of the aft cavity are somewhat different. The results shown in Fig. 5–8 for the stationary wall at the same radial locations as the results shown for the rotor indicate that the coolant concentrations at the static wall are much more sensitive to coolant flow rate. Note in Fig. 5–8 that at the non-dimensional radii of 0.925 and 0.775, the coolant concentration falls off rapidly with a decrease in coolant flow rate.

The results shown in Fig. 5–9 show the cavity coolant concentrations at the different radii as a function of coolant flow rate. The local boundary layer entrainment flow for a "free disk" is shown for comparison. The results shown in Fig. 5–9 indicate that an 80 percent cavity purge can be achieved if the coolant flow rate is on the order of 1/2 the local "free disk" entrainment flow rate.

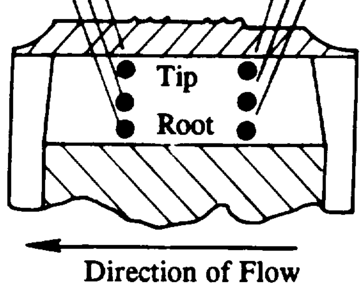
Results on the effects of flow rate on the coolant concentration in the front cavity were found to be similar to those found for the aft cavity. Fig. 5–10 shows wall concentration measurements with coolant flow rate for two radii in the front cavity. For this cavity, the coolant source is source 12. The free disk entrainment flow at the rotor 1 blade attachment radius is shown in Fig. 5–10 for comparison. Flow conditions at which accurate source distributions could be made were limited due to a leak which developed in the stationary–to–rotating frame air transfer system. A carbon seal was found to operate properly only over a small range of flow rates to the center cavity. Fortunately, this occurred after the front cavity tests were completed as the problem affected the amount of flow that could be delivered to the front cavity.

REGION VI - Rotor 2 Blade Shanks

S - Suction Surface

LOC	φ_{12}	φ_{13}	φ_{14}	φ_{01}	φ_{03}
B13	0.22	0.13	0.00	0.35	0.29
B12	0.22	0.13	0.02	0.33	0.30
B11	0.21	0.12	0.06	0.33	0.29

LOC	φ_{12}	φ_{13}	φ_{14}	φ_{01}	φ_{03}
B20	0.23	0.13	0.02	0.34	0.27
B21	0.23	0.13	0.02	0.34	0.26
B22	0.22	0.21	0.02	0.30	0.23



P - Pressure Surface

LOC	φ_{12}	φ_{13}	φ_{14}	φ_{01}	φ_{03}
B16	0.23	0.13	0.02	0.34	0.28
B15	0.23	0.13	0.02	0.33	0.29
B14	0.23	0.13	0.00	0.35	0.30

LOC	φ_{12}	φ_{13}	φ_{14}	φ_{01}	φ_{03}
B17	0.23	0.13	0.02	0.34	0.26
B18	0.23	0.13	0.02	0.34	0.27
B19	0.23	0.13	0.02	0.34	0.27

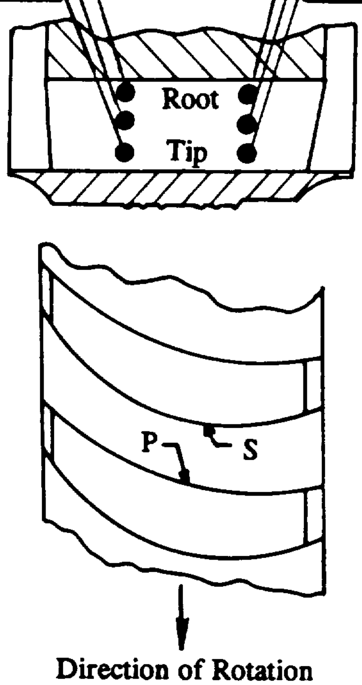
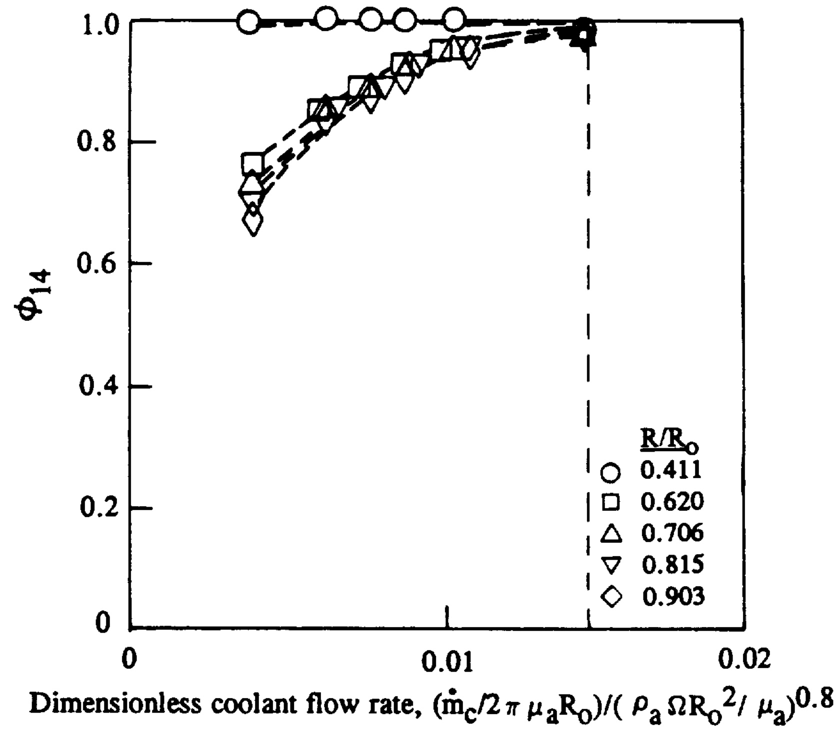


Figure 5-7. Gas Source Measurement Results for Flow Condition 202 in Region VI - Rotor 2 Blade Shanks

Variables:
Radius
Coolant flow rate

Region IV: Aft Cavity & Rotor 2
Coolant: Air (Source 14)

a) Rotor Wall



b) Stationary Wall

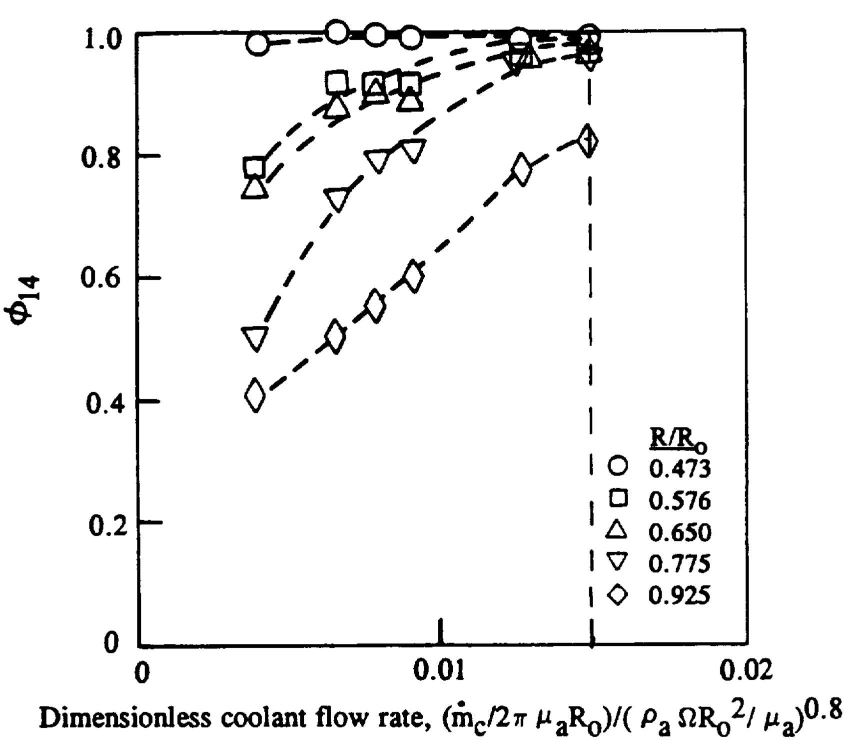
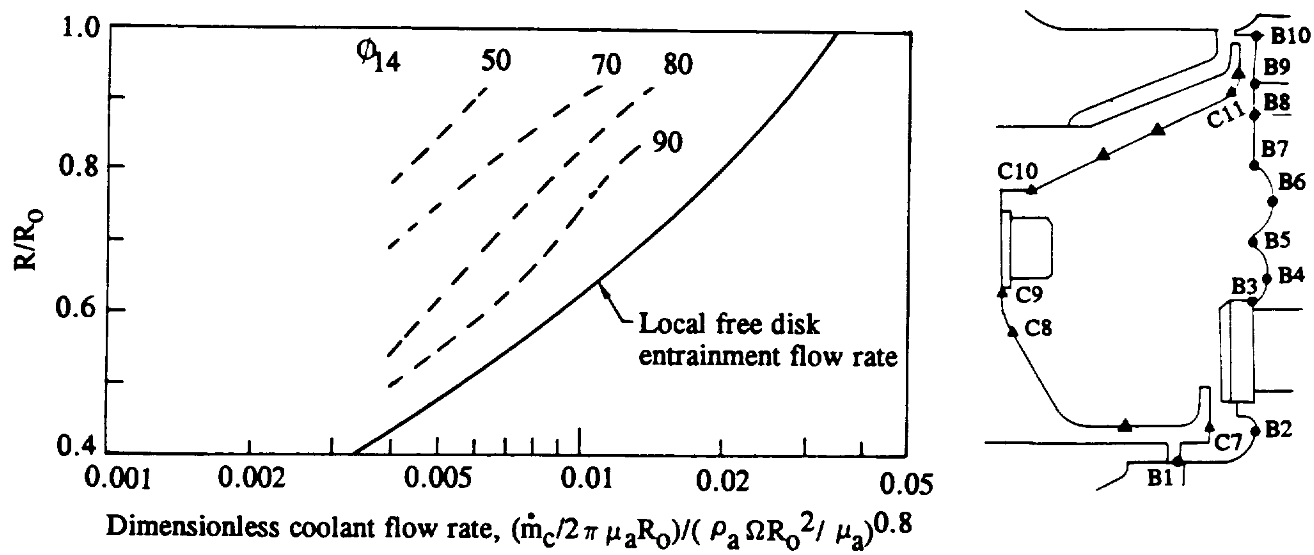


Figure 5-8. Coolant Concentration on Rotor and Stationary Walls in Region IV - Aft Cavity and Rotor 2

a) Coolant Distribution on Stationary Wall
Region IV: Aft Cavity & Rotor 2
Coolant: Air



b) Coolant Distribution on Rotor
Region IV: Aft Cavity & Rotor 2
Coolant: Air

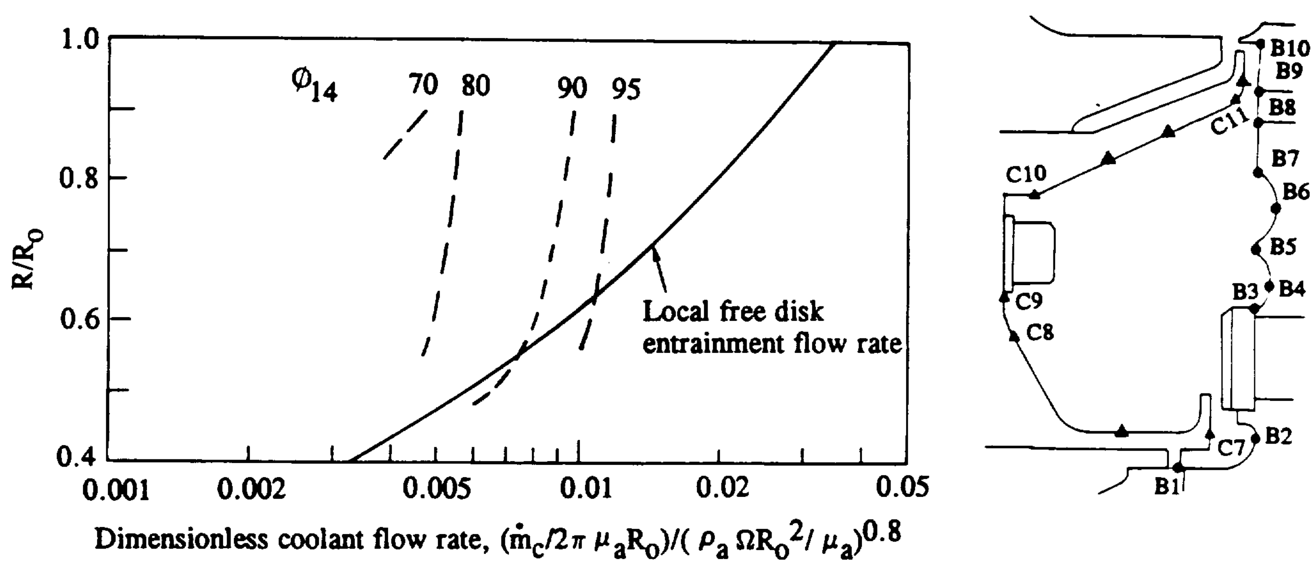


Figure 5-9. Coolant Air Distributions on Rotor and Stationary Walls in Region IV - Aft Cavity and Rotor 2 With Air as Coolant

See Figure 5-2 for location of gas source measurements

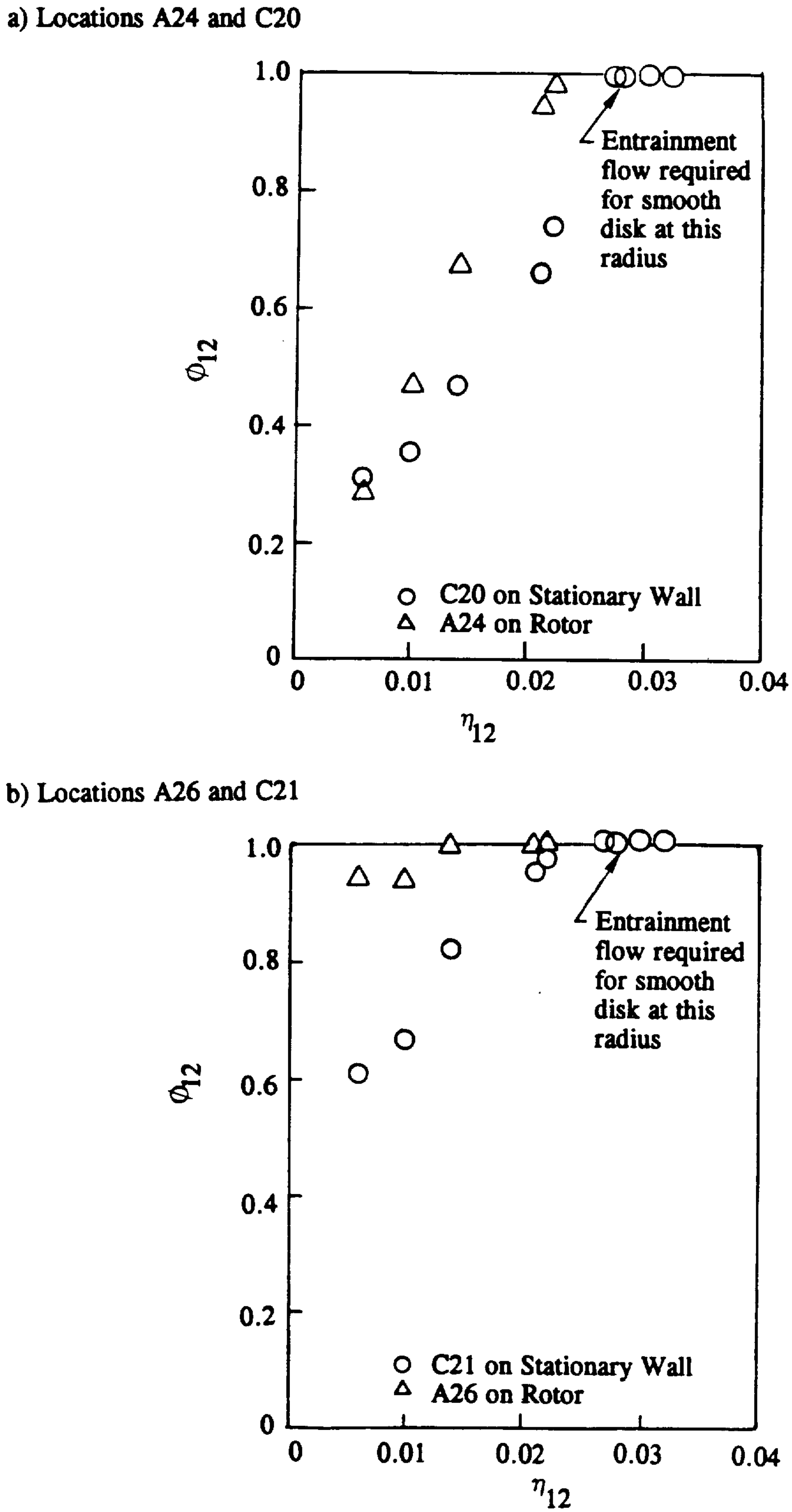


Figure 5-10. Variation of Coolant Concentrations With Coolant Flow Parameter at Selected Locations on Rotor and Stationary Walls in Region I - Forward Cavity and Rotor 1

5.3 Effects of Coolant Density Ratio

In the SSME HPFTP, the coolant is cold H_2 which has a density approximately four times that of the main gas path fluid. To determine the effects that coolant density has on cavity coolant concentrations, CO_2 was used as the coolant in the aft cavity of the model. CO_2 has a density which is approximately 1.5 times that of air. The experimental results obtained for these tests should be considered only as exploratory in nature because the density ratio is far below the value in the actual engine. Gases such as sulfur dioxide could be used to simulate the actual density ratios in future isothermal tests.

Coolant concentrations at five radial locations in the aft cavity are presented in Fig. 5–11 for the rotating and stationary walls. The results indicate significant differences between rotor and stator coolant concentrations at similar radii. At the higher radii and at the lowest coolant flow rates the coolant concentrations on the rotor are approximately three times higher than those measured on the static walls. The coolant concentrations measured on the static wall appear to be more sensitive to coolant flow rate than those measured on the rotor. This finding is consistent with findings for the baseline tests where air was used as the coolant and the density ratio was 1 (Fig. 5–8). Note in Fig. 5–11 that even at the lower radii, the static wall coolant concentration appears to fall off rapidly with decreasing coolant flow rate.

The results of aft cavity coolant concentration measurements obtained for air and CO_2 are compared in Fig. 5–12. Here, results for two radii are presented for both rotating and stationary walls. The results shown in Fig. 5–12 indicate that coolant density has a strong effect on coolant concentration on both rotating and stationary walls when compared with the constant density baseline test results.

Coolant distributions for static and rotating walls at various radii in the aft cavity are presented in Fig. 5–13 for the tests with CO_2 as the coolant. The local free disk entrainment flow is shown for comparison. Note from Fig. 5–13 that on the static wall, coolant flow rates on the order of the local free disk entrainment flow are required to achieve a 70 to 75 percent coolant distribution on the static wall. This result may be due to increased mixing and possible instability of the rotating flow in the cavity due to the higher gas densities at the lower radii. A more sophisticated experimental approach using a gas heavier than CO_2 as the coolant should be conducted to ascertain a more detailed description of the flow characteristics in this flow situation.

5.4 Effects of Reynolds Number

The results reported above were obtained at test conditions where the disk tangential Reynolds number, Ret, was approximately 2.2×10^6. Some tests were conducted at a tangential Reynolds number of approximately 1.6×10^6. These tests were performed to determine the affect of Reynolds number on the cavity coolant distribution.

Fig. 5–14 presents results for several stationary and rotating locations as noted. The coolant concentrations are those from source 12. Data from Test 101 and Test 201 with the same coolant flow parameters were used for the comparison. The results shown in Fig. 5–14 indicate that there were no appreciable differences in the coolant concentration from source 12 at these locations for the two Reynolds numbers investigated. This indicates that the present data of Re $\approx 10^6$ may be safely extrapolated to the actual engine Re $\approx 10^7$.

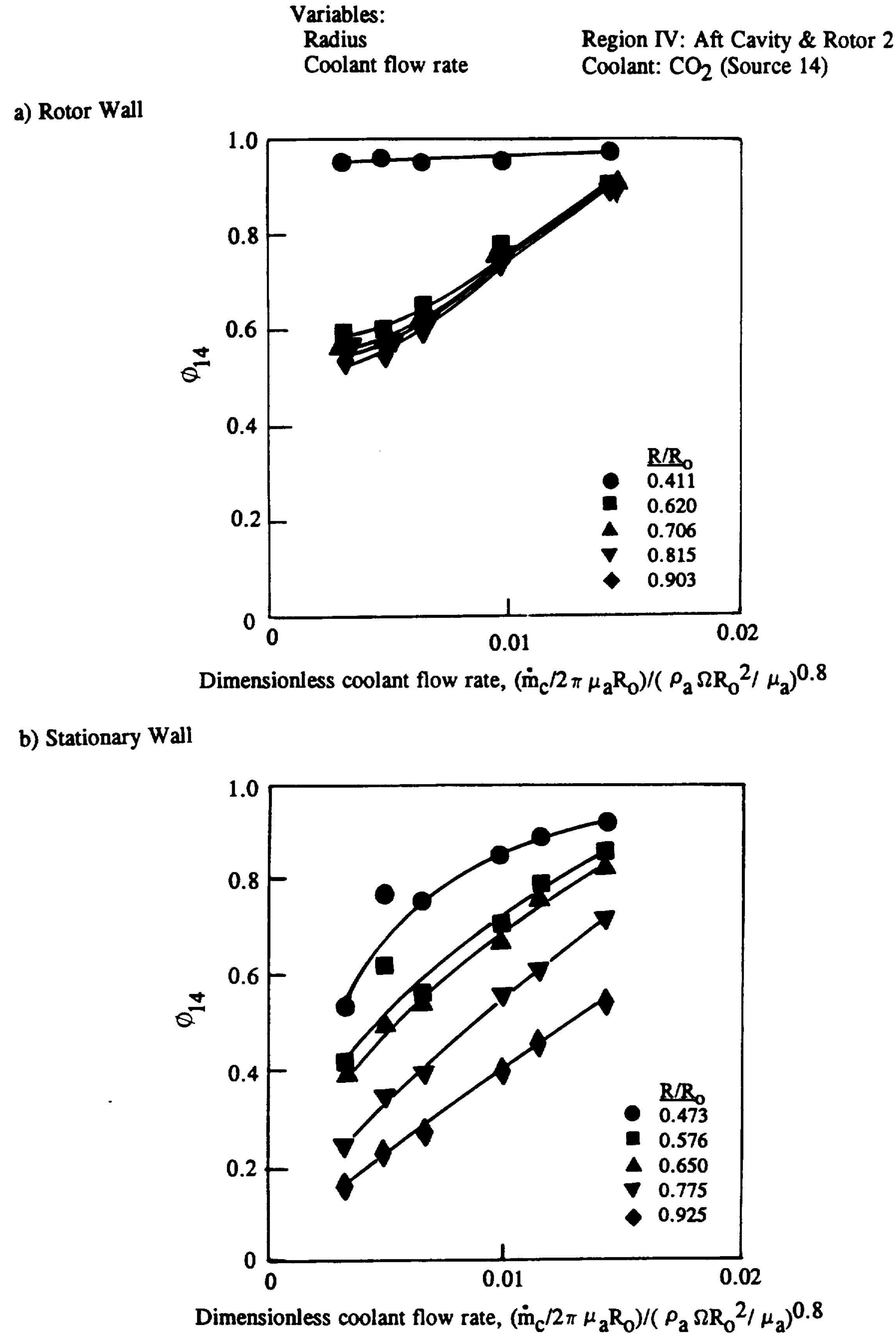


Figure 5-11. Variation of Coolant Concentration With Coolant Flow Parameter on Rotor and Stationary Walls in Region IV - Aft Cavity and Rotor 2 With CO_2 as Coolant

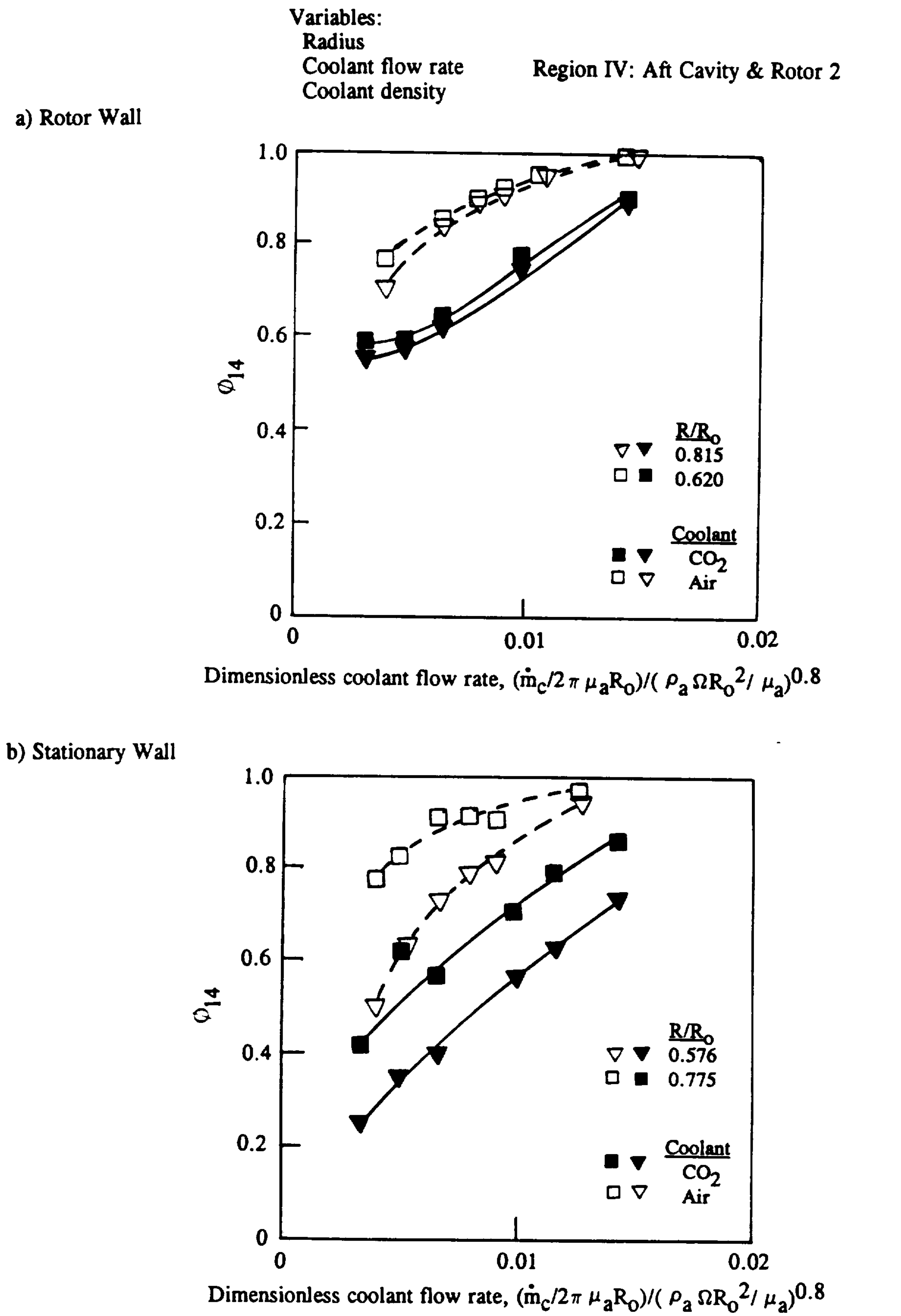
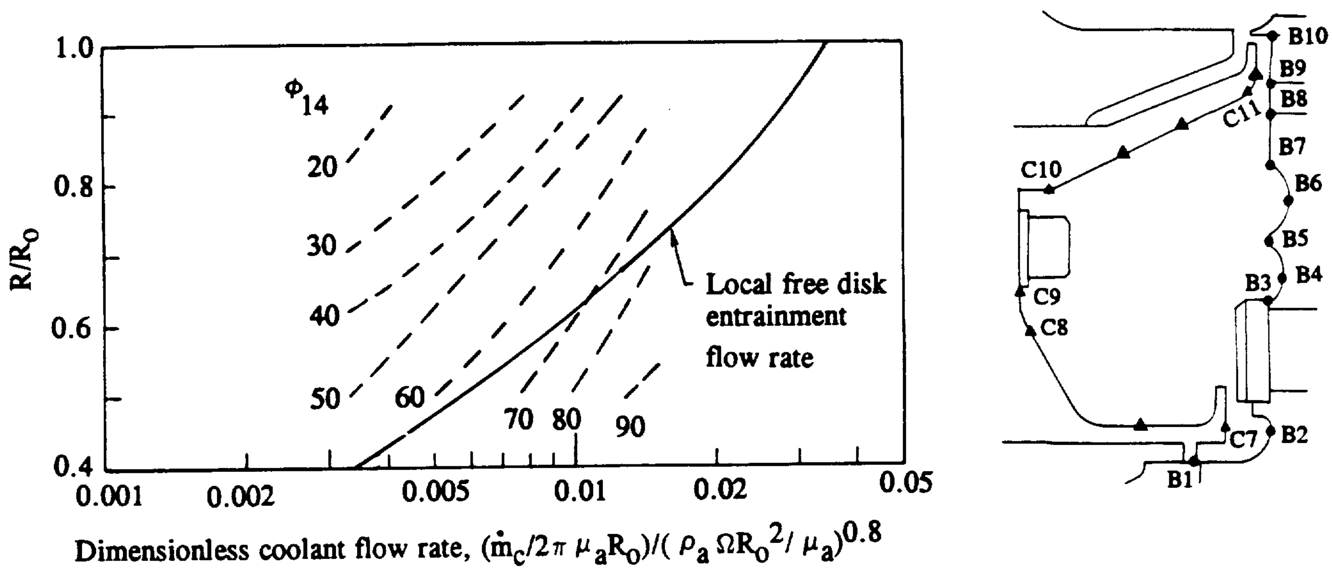


Figure 5-12. Effect of Coolant Density and Coolant Flow Parameter on Coolant Distribution in Region IV - Aft Cavity and Rotor 2

a) Coolant Distribution on Stationary Wall
Region IV: Aft Cavity & Rotor 2
Coolant: CO_2



b) Coolant Distribution on Rotor
Region IV: Aft Cavity & Rotor 2
Coolant: CO_2

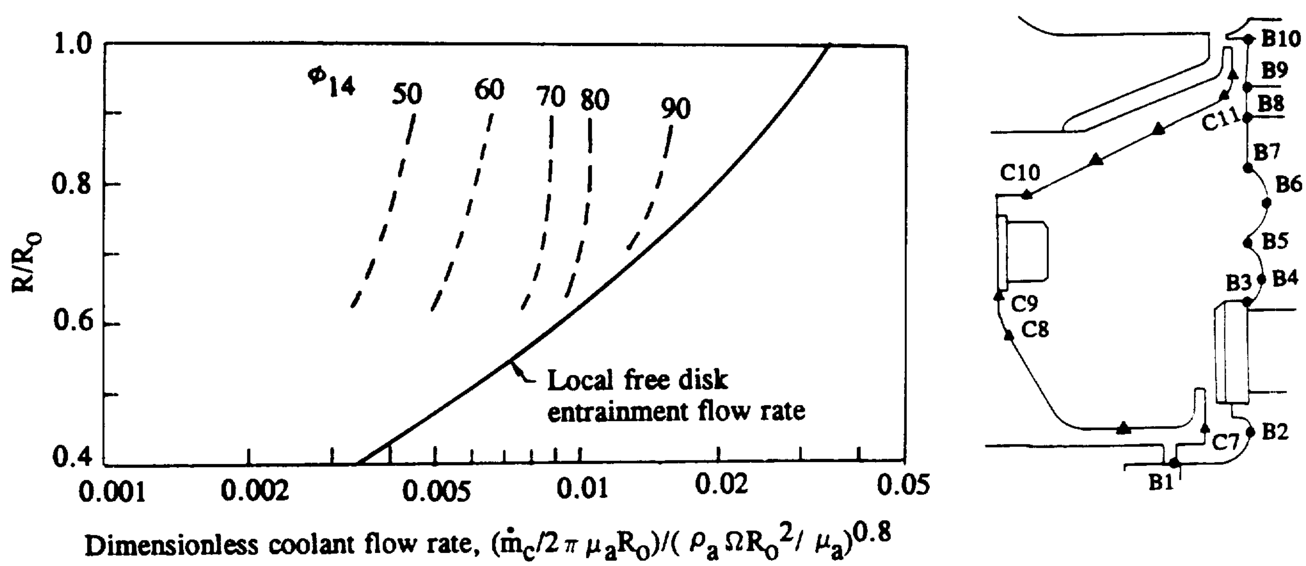


Figure 5-13. Coolant Distributions on Rotor and Stationary Walls in Region IV - Aft Cavity and Rotor 2 With CO_2 as Coolant

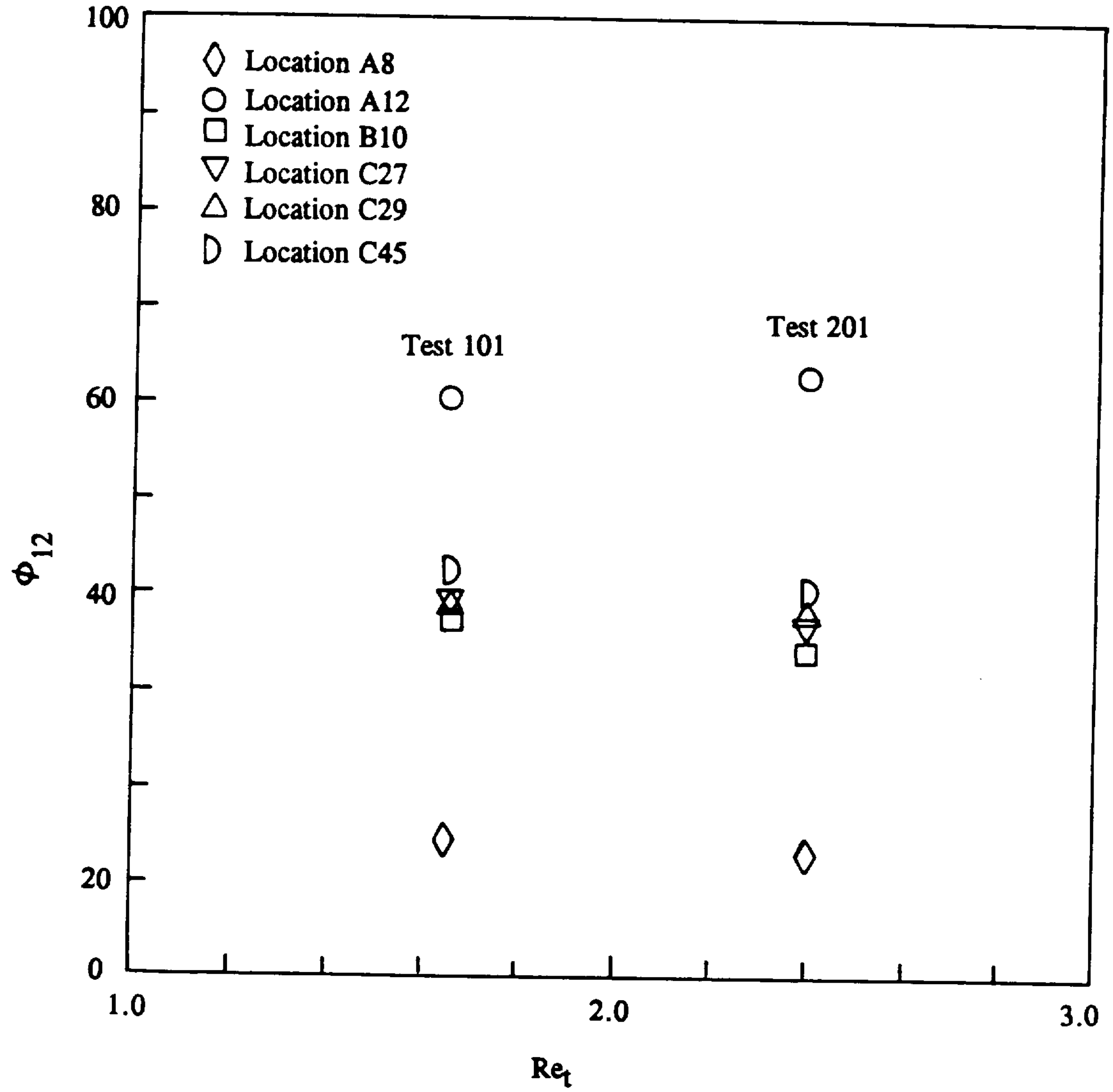


Figure 5-14. Effect of Reynolds Number on Concentrations at Selected Locations for Constant Coolant Flow Parameters

6.0 CONCLUDING REMARKS AND CONCLUSIONS

A series of experiments were conducted to determine the various aerodynamic driving mechanisms influencing the sources of gases on the disk cavity surfaces. Following are observations regarding these flows and driving mechanisms.

1. The disks adjacent to the forward and aft cavity walls entrained the coolant injected near inner radii of these disks. The concentration of coolant from that rotor cavity on the rotor was always near 100 percent when the coolant flow rate was greater than the local free disk entrainment flow rate. This indicates that the coolant flow is well attached to the rotating disk.

2. The local cavity coolant concentration on the forward and aft cavity walls was generally (3% to 70%) less than the concentration on the rotor at the same radius. This indicated that ingested flow in the forward cavity and flow through the blade shanks in the aft cavity was mixing with the coolant coming from the rotor and recirculating inward along the cavity wall.

3. Coolant density ratio has a strong effect on the coolant distribution in the cavity. The coolant concentration on the rotor for $\rho_c/\rho_a = 1.5$ decreased by typically 1 to 15 percent from the results for $\rho_c/\rho_a = 1.0$ at both comparable coolant weight flow rates or comparable coolant volume flow rates. The coolant concentration on the aft cavity wall also decreased significantly by typically 10 to 50 percent from $\rho_c/\rho_a = 1.0$ results at comparable flow rates.

4. The gas source distribution on the near surface of the upstream rotor was similar to that on its upstream surface. The concentration of inner seal coolant concentration was high in this region. This indicates that coolant attached to the rotor does not readily mix with the fluid in the cavity.

5. The gas source distribution on the front surface of the rear rotor had inner stage coolant concentrations of 30 percent or less on the radial regions of the rotor. These low concentrations were attributed to the uneven flow split of the inner cavity coolant flow rate. A relatively low flow of inner cavity coolant occurred downstream across the three-stage labyrinth seal and a larger fraction of the coolant flowed upstream toward the upstream rotor.

6. Most of the gas path fluid ingested across the first vane/first blade rim seal flowed directly through the first rotor in the area between blade shanks. A modest amount of mixing or radial redistribution occurred between the ingested gas and the forward cavity coolant.

7.0 TABULATED DATA

Table 7-1 Table of Flow Conditions for Concentration Measurement Tests

Test No.	Ω rpm	P psia	Re x10^{-6}	η_{12}	η_{13}	η_{14}	Coolant (14)
101	1003	60.55	1.65	0.027	0.014	0.012	Air
102	1004	60.55	1.64	0.027	0.012	0.012	Air
103	1000	58.11	1.57	0.029	0.011	0.013	Air
104	1000	59.91	1.61	0.027	0.014	0.025	Air
105	1001	52.83	1.44	0.037	0.018	0.012	Air
201	1502	57.37	2.38	0.027	0.013	0.013	Air
202	1502	57.24	2.19	0.017	0.008	0.013	Air
203	1500	58.50	2.21	0.028	0.014	0.012	Air
204	1501	54.54	2.25	0.030	0.014	0.015	Air
205	1504	57.79	2.24	0.030	0.015	0.014	Air
206	1502	54.12	2.18	0.032	0.015	0.015	Air
210	1497	60.90	2.48	0.024	0.012	0.014	Air
211	1503	61.02	2.46	0.022	0.011	0.014	Air
212	1495	61.02	2.44	0.020	0.010	0.014	Air
213	1492	60.99	2.43	0.014	0.007	0.014	Air
214	1493	61.34	2.45	0.010	0.005	0.014	Air
220	1495	61.09	2.48	0.022	0.013	0.014	Air
221	1494	61.08	2.45	0.021	0.011	0.014	Air
222	1493	61.29	2.45	0.014	0.007	0.014	Air
223	1492	61.76	2.42	0.010	0.002	0.014	Air
224	1492	61.70	2.42	0.006	0.005	0.014	Air
225	1496	61.60	2.37	0.001	0.002	0.014	Air
231	1494	62.66	2.40	0.025	0.013	0.011	Air
232	1494	62.46	2.39	0.025	0.013	0.009	Air
233	1493	62.38	2.39	0.025	0.013	0.008	Air
234	1494	62.22	2.39	0.025	0.013	0.007	Air
235	1494	62.44	2.41	0.024	0.013	0.004	Air
241	1499	62.31	2.37	0.025	0.014	0.014	CO_2
243	1497	62.43	2.36	0.025	0.014	0.014	CO_2
244	1496	62.58	2.37	0.025	0.014	0.011	CO_2
245	1495	47.80	1.80	0.028	0.016	0.009	CO_2
246	1495	62.66	2.34	0.025	0.014	0.005	CO_2
247	1495	62.59	2.34	0.025	0.014	0.003	CO_2
248	1495	62.81	2.34	0.025	0.014	0.007	CO_2
249	1496	62.83	2.34	0.025	0.014	0.010	CO_2

Tables 7-2 through 7-36 Flow and Seal Test Parameters and Gas Source Concentrations

Note: Tables follow on pages 46 through 91 for Gas Source Measurement Tests listed in Table 7-1.

FLOW AND SEAL TEST PARAMETERS FOR TEST 101 ON 3/25/91

Parameter	Seal 1	Seal 2	Seal 3	Seal 4	Forward	Inner	Aft
	LOCATION						
Ω, Rpm	1003	1003	1003	1003	1003	1003	1003
P, psia	60.55	60.18	59.66	59.44	59.82	60.03	59.97
T, °R	510	511	512	512	516	515	517
Rho, lb/(ft^3)	0.320	0.318	0.315	0.313	0.313	0.315	0.313
Emdot, lb/sec	-0.139	-0.089	0.262	0.211	0.142	0.075	0.064
μ, lb/(ft sec)	1.17E-05	1.18E-05	1.18E-05	1.18E-05	1.18E-05	1.18E-05	1.19E-05
Ro, in	9.12	9.12	9.12	9.12	9.12	9.12	9.12
Vo, ft/sec	79.800	79.800	79.800	79.800	79.800	79.800	79.800
Vϕ, ft/sec	151.414	0	110.772	0	-	-	-
Vz, ft/sec	50.500	48.541	40.202	47.496	-	-	-
Qo, psi	0.220	0.220	0.220	0.220	0.220	0.220	0.220
δp/q	0	-1.696	-4.070	-5.059	-3.347	-2.385	-2.662
Vϕ/Vo	1.897	0	1.388	0	-	-	-
Vz/Vo	0.633	0.608	0.504	0.595	-	-	-
Reto	1.65E+06	1.65E+06	1.65E+06	1.65E+06	1.65E+06	1.65E+06	1.65E+06
Rer	-2472	-1579	4655	3759	2508	1325	1121
Rer/(Ret^0.8)	-0.026	-0.017	0.049	0.040	0.027	0.014	0.012
Mϕ	0.137	0	0.100	0	-	-	-
Coolant Gas	-	-	-	-	Air	Air	Air

GAS SOURCE CONCENTRATION

TEST	-	PORT	ϕ12	ϕ13	ϕ14	ϕ01	ϕ03	ϕ05	ϕ07	TOTAL
101	A	1	0.00	0.98	-0.00	0.00	0.00	-	-	0.98
		2	0.00	0.99	0.00	0.00	0.00	-	-	0.99
		3	0.00	0.98	0.00	0.00	0.00	-	-	0.98
		4	0.01	0.98	0.00	0.01	0.00	-	-	1.00
		5	0.01	0.98	0.00	0.01	0.00	-	-	1.00
		6	0.01	0.96	0.00	0.01	0.01	-	-	0.99
		7	0.02	0.94	0.00	0.02	0.01	-	-	0.99
		8	0.14	0.70	0.00	0.10	0.04	-	-	0.98
		9	0.30	0.40	0.00	0.22	0.07	-	-	0.99
		10	0.41	0.00	0.00	0.33	0.26	-	-	1.00
		11	-	-	-	-	-	-	-	-
		12	0.60	0.01	0.00	0.39	0.00	-	-	1.00
		13	0.60	0.01	0.00	0.40	0.00	-	-	1.00
		14	0.51	0.01	0.00	0.48	0.00	-	-	1.00
		15	0.57	0.01	0.00	0.45	0.00	-	-	1.03
		16	0.63	0.01	0.00	0.37	0.00	-	-	1.01
		17	0.65	0.01	0.00	0.37	0.00	-	-	1.03
		18	0.55	0.01	0.00	0.43	0.00	-	-	0.99
		19	-	-	-	-	-	-	-	-
		20	0.54	0.01	0.00	0.47	0.00	-	-	1.02
		21	0.77	0.01	0.00	0.24	0.00	-	-	1.02
		22	0.92	0.00	-0.01	0.11	0.00	-	-	1.02
		23	0.13	0.00	-0.01	0.91	0.00	-	-	1.03
		24	1.02	0.00	-0.01	0.02	0.00	-	-	1.03
		25	1.02	0.00	-0.02	0.02	0.00	-	-	1.02
		26	1.01	0.00	-0.02	0.02	0.00	-	-	1.01
		27	1.02	0.00	-0.03	0.02	0.00	-	-	1.01
		28	1.02	0.00	-0.04	0.02	0.00	-	-	1.00
		29	1.01	0.00	-0.04	0.02	0.00	-	-	0.99
		30	1.01	0.01	-0.04	0.02	0.01	-	-	1.01
		31	1.02	0.00	-0.05	0.02	0.01	-	-	1.00
		32	1.02	0.00	-0.05	0.02	0.01	-	-	1.00
		33	1.02	0.00	-0.05	0.02	0.00	-	-	0.99
		34	0.01	0.97	-0.05	0.02	0.00	-	-	0.95
		35	0.01	0.97	-0.05	0.02	0.01	-	-	0.96
		36	0.00	0.97	-0.05	0.02	0.01	-	-	0.95
		37	0.00	0.97	-0.05	0.02	0.01	-	-	0.95
		38	0.00	0.97	-0.05	0.02	0.01	-	-	0.95
		39	0.00	0.97	-0.05	0.02	0.01	-	-	0.95
	B	1	0.01	0.01	1.02	0.01	0.01	-	-	1.06
		2	0.01	0.01	1.01	0.01	0.01	-	-	1.05
		3	0.02	0.01	0.99	0.02	0.01	-	-	1.05
		4	0.02	0.01	0.98	0.02	0.01	-	-	1.04

GAS SOURCE CONCENTRATION (Cont.)

TEST	-	PORT	φ12	φ13	φ14	φ01	φ03	φ05	φ07	TOTAL
101	B	5	0.02	0.01	0.98	0.02	0.01	-	-	1.04
		6	0.02	0.01	0.99	0.02	0.01	-	-	1.05
		7	0.02	0.01	0.99	0.02	0.01	-	-	1.05
		8	0.02	0.01	0.97	0.02	0.01	-	-	1.03
		9	0.02	0.01	0.97	0.02	0.01	-	-	1.03
		10	0.37	0.19	0.03	0.28	0.16	-	-	1.03
		11	0.37	0.29	0.02	0.27	0.16	-	-	1.01
		12	0.37	0.20	0.01	0.28	0.16	-	-	1.02
		13	0.38	0.20	0.01	0.28	0.16	-	-	1.03
		14	0.37	0.20	0.01	0.28	0.16	-	-	1.02
		15	0.38	0.20	0.01	0.28	0.16	-	-	1.03
		16	0.37	0.20	0.01	0.29	0.16	-	-	1.03
		17	0.38	0.20	0.01	0.29	0.16	-	-	1.04
		18	0.38	0.20	0.01	0.29	0.16	-	-	1.04
		19	0.37	0.20	0.01	0.29	0.16	-	-	1.03
		20	0.38	0.20	0.01	0.29	0.16	-	-	1.04
		21	0.37	0.20	0.01	0.28	0.16	-	-	1.02
		22	0.33	0.28	0.00	0.26	0.14	-	-	1.01
		23	0.38	0.19	-0.00	0.30	0.16	-	-	1.03
		24	0.37	0.21	-0.01	0.28	0.16	-	-	1.01
		25	0.36	0.25	-0.01	0.28	0.15	-	-	1.03
		26	0.33	0.30	-0.02	0.25	0.14	-	-	1.00
		27	0.30	0.35	-0.02	0.24	0.13	-	-	1.00
		28	0.26	0.42	-0.03	0.21	0.12	-	-	0.98
		29	0.26	0.43	-0.03	0.21	0.12	-	-	0.99
		30	0.09	0.81	-0.04	0.08	0.05	-	-	0.99
	C	1	0.00	0.00	0.00	1.02	0.00	-	-	1.02
		2	0.00	0.00	0.00	0.01	0.99	-	-	1.00
		3	0.00	0.00	-0.00	0.00	0.01	-	-	0.01
		4	0.00	0.00	0.00	0.00	0.00	-	-	0.00
		5	1.00	0.00	0.00	0.00	0.00	-	-	1.00
		6	0.00	0.98	0.00	0.00	0.00	-	-	0.98
		7	0.01	0.01	0.98	0.01	0.00	-	-	1.01
		8	0.02	0.01	0.96	0.02	0.01	-	-	1.02
		9	0.02	0.01	0.94	0.02	0.01	-	-	1.00
		10	0.02	0.01	0.93	0.02	0.01	-	-	0.99
		11	0.07	0.04	0.79	0.06	0.03	-	-	0.99
		12	0.08	0.04	0.10	0.06	0.04	-	-	0.32
		13	0.02	0.01	0.00	0.02	0.01	-	-	0.06
		14	0.00	0.00	0.00	0.01	0.99	-	-	1.00
		15	0.00	0.00	0.00	1.02	0.01	-	-	1.03
		16	0.00	0.00	0.00	1.04	0.00	-	-	1.04
		17	0.00	0.00	0.00	1.05	0.01	-	-	1.06
		18	0.00	0.00	0.00	1.04	0.00	-	-	1.04
		19	0.01	0.00	0.00	1.04	0.00	-	-	1.05
		20	1.00	0.00	0.00	0.02	0.00	-	-	1.02
		21	1.01	0.00	0.00	0.02	0.00	-	-	1.03
		22	1.01	0.00	-0.01	0.02	0.00	-	-	1.02
		23	1.01	0.00	-0.01	0.02	0.00	-	-	1.02
		24	1.02	0.00	-0.02	0.02	0.00	-	-	1.02
		25	0.37	0.17	-0.02	0.28	0.16	-	-	0.96
		26	0.39	0.18	-0.03	0.28	0.15	-	-	0.97
		27	0.39	0.18	-0.03	0.28	0.15	-	-	0.97
		28	0.38	0.17	-0.04	0.29	0.15	-	-	0.95
		29	0.38	0.16	-0.04	0.28	0.17	-	-	0.95
		30	0.38	0.17	-0.04	0.29	0.16	-	-	0.96
		31	0.38	0.18	-0.04	0.29	0.16	-	-	0.97
		32	0.35	0.24	-0.04	0.27	0.16	-	-	0.98
		33	0.33	0.26	-0.04	0.26	0.15	-	-	0.96
		34	0.01	0.96	-0.04	0.03	0.01	-	-	0.97
		35	0.01	0.97	-0.04	0.03	0.01	-	-	0.98
		36	0.01	0.97	-0.04	0.03	0.01	-	-	0.98
		37	0.01	0.97	-0.04	0.03	0.01	-	-	0.98
		38	0.01	0.94	-0.03	0.03	0.01	-	-	0.96
		39	0.03	0.92	-0.04	0.04	0.02	-	-	0.97
		40	0.03	0.90	-0.04	0.05	0.02	-	-	0.96
		41	0.09	0.79	-0.04	0.09	0.04	-	-	0.97
		42	0.25	0.44	-0.04	0.20	0.10	-	-	0.95
		43	0.32	0.31	-0.04	0.25	0.13	-	-	0.97
		44	0.39	0.17	-0.04	0.29	0.18	-	-	0.99
		45	0.42	0.09	-0.04	0.34	0.18	-	-	0.99
		46	0.40	0.12	-0.04	0.32	0.17	-	-	0.97
		47	0.02	0.01	-0.04	0.04	0.98	-	-	1.01
		48	0.01	0.01	-0.04	0.03	1.01	-	-	1.02

FLOW AND SEAL TEST PARAMETERS FOR TEST 102 ON 3/22/91

Parameter	LOCATION						
	Seal 1	Seal 2	Seal 3	Seal 4	Forward	Inner	Aft
Ω, Rpm	1004	1004	1004	1004	1004	1004	1004
P, psia	60.15	59.82	59.32	59.09	59.47	59.68	59.62
T, °R	511	511	513	513	515	514	516
Rho, lb/(ft^3)	0.318	0.316	0.312	0.311	0.312	0.313	0.312
Emdot, lb/sec	−0.126	−0.094	0.265	0.208	0.143	0.062	0.066
μ, lb/(ft sec)	1.18E−05	1.18E−05	1.18E−05	1.18E−05	1.18E−05	1.18E−05	1.19E−05
Ro, in	9.12	9.12	9.12	9.12	9.12	9.12	9.12
Vo, ft/sec	79.890	79.890	79.890	79.890	79.890	79.890	79.890
Vϕ, ft/sec	150.175	0	109.518	0	-	-	-
Vz, ft/sec	50.086	48.190	39.747	46.885	-	-	-
Qo, psi	0.219	0.219	0.219	0.219	0.219	0.219	0.219
δp/q	0	−1.500	−3.782	−4.862	−3.116	−2.132	−2.414
Vϕ/Vo	1.880	0	1.371	0	-	-	-
Vz/Vo	0.627	0.603	0.498	0.587	-	-	-
Reto	1.64E+06	1.64E+06	1.64E+06	1.64E+06	1.64E+06	1.64E+06	1.64E+06
Rer	−2241	−1667	4699	3696	2534	1106	1167
Rer/(Ret^0.8)	−0.024	−0.018	0.050	0.039	0.027	0.012	0.012
Mϕ	0.135	0	0.099	0	-	-	-
Coolant Gas	-	-	-	-	Air	Air	Air

GAS SOURCE CONCENTRATION

TEST	-	PORT	ϕ12	ϕ13	ϕ14	ϕ01	ϕ03	ϕ05	ϕ07	TOTAL
102	A	1	0.09	0.91	0.00	−0.00	0.00	0.00	-	1.00
		2	0.09	0.91	0.00	−0.00	−0.00	0.00	-	1.00
		3	0.10	0.91	0.00	−0.00	0.00	−0.00	-	1.01
		4	0.10	0.90	0.00	0.00	0.00	0.00	-	1.00
		5	0.10	0.89	0.00	0.01	0.00	0.00	-	1.00
		6	0.11	0.87	0.00	0.01	0.01	0.00	-	1.00
		7	0.12	0.86	0.00	0.02	0.01	0.00	-	1.00
		8	0.20	0.67	0.00	0.08	0.05	0.00	-	1.00
		9	0.34	0.38	0.00	0.20	0.08	0.00	-	1.01
		10	0.38	0.00	0.00	0.29	0.33	0.00	-	1.00
		11	-	-	-	-	-	-	-	-
		12	0.63	0.01	0.00	0.38	0.00	0.00	-	1.02
		13	0.62	0.00	0.00	0.40	0.00	0.00	-	1.03
		14	0.54	0.01	0.00	0.47	0.00	0.00	-	1.03
		15	0.58	0.01	0.00	0.44	0.00	0.00	-	1.03
		16	0.67	0.01	0.00	0.35	0.01	0.00	-	1.03
		17	0.66	0.01	0.00	0.36	0.01	0.01	-	1.04
		18	0.59	0.01	0.00	0.44	0.01	0.01	-	1.05
		19	-	-	-	-	-	-	-	-
		20	0.55	0.01	0.00	0.46	0.01	0.01	-	1.03
		21	0.78	0.01	0.00	0.24	0.01	0.01	-	1.04
		22	0.93	0.01	0.00	0.10	0.01	0.01	-	1.06
		23	0.14	0.01	0.00	0.90	0.01	0.01	-	1.06
		24	1.03	0.01	0.01	0.01	0.01	0.01	-	1.06
		25	1.03	0.01	0.01	0.00	0.01	0.01	-	1.07
		26	1.03	0.01	0.01	0.00	0.01	0.01	-	1.07
		27	1.03	0.01	0.01	0.00	0.01	0.01	-	1.07
		28	1.06	0.01	0.01	0.00	0.01	0.01	-	1.10
		29	1.07	0.01	0.01	0.00	0.01	0.01	-	1.11
		30	1.06	0.02	0.01	0.00	0.01	0.01	-	1.10
		31	1.06	0.01	0.01	0.00	0.01	0.01	-	1.10
		32	1.05	0.01	0.01	0.00	0.01	0.01	-	1.10
		33	1.06	0.01	0.01	0.00	0.01	0.01	-	1.10
		34	0.11	0.91	0.01	0.00	0.01	0.01	-	1.05
		35	0.11	0.93	0.01	0.00	0.01	0.01	-	1.06
		36	0.11	0.91	0.01	0.00	0.01	0.01	-	1.04
		37	0.11	0.92	0.01	0.00	0.01	0.01	-	1.06
		38	0.11	0.92	0.01	0.00	0.01	0.01	-	1.06
		39	0.11	0.92	0.01	−0.01	0.02	0.01	-	1.05
	B	1	0.01	0.01	1.01	0.01	0.00	0.01	-	1.04
		2	0.01	0.01	1.00	0.01	0.00	0.01	-	1.03
		3	0.01	0.01	0.98	0.01	0.01	0.01	-	1.03
		4	0.01	0.01	0.97	0.01	0.01	0.01	-	1.02

GAS SOURCE CONCENTRATION (Cont.)

TEST	-	PORT	φ12	φ13	φ14	φ01	φ03	φ05	φ07	TOTAL
102	B	5	0.01	0.01	0.98	0.01	0.01	0.01	-	1.02
		6	0.01	0.01	0.97	0.01	0.01	0.01	-	1.02
		7	0.02	0.01	0.97	0.01	0.01	0.01	-	1.02
		8	0.02	0.01	0.97	0.01	0.01	0.01	-	1.02
		9	0.02	0.01	0.98	0.01	0.01	0.01	-	1.03
		10	0.39	0.18	0.03	0.25	0.18	0.01	-	1.03
		11	0.39	0.18	0.02	0.25	0.18	0.01	-	1.02
		12	0.39	0.18	0.02	0.24	0.19	0.01	-	1.02
		13	0.39	0.18	0.01	0.25	0.19	0.01	-	1.03
		14	0.40	0.18	0.01	0.24	0.19	0.01	-	1.03
		15	0.39	0.18	0.01	0.25	0.19	0.01	-	1.03
		16	0.39	0.18	0.01	0.24	0.19	0.01	-	1.03
		17	0.39	0.18	0.01	0.24	0.19	0.01	-	1.03
		18	0.39	0.19	0.01	0.25	0.19	0.01	-	1.04
		19	0.39	0.18	0.01	0.26	0.19	0.01	-	1.04
		20	0.39	0.18	0.01	0.25	0.19	0.01	-	1.04
		21	0.39	0.19	0.01	0.25	0.19	0.00	-	1.03
		22	0.36	0.26	0.01	0.22	0.17	0.00	-	1.02
		23	0.39	0.18	0.01	0.25	0.19	0.00	-	1.03
		24	0.39	0.20	0.01	0.24	0.19	0.00	-	1.04
		25	0.37	0.23	0.02	0.23	0.19	0.00	-	1.04
		26	0.35	0.29	0.02	0.21	0.17	0.00	-	1.03
		27	0.33	0.33	0.02	0.20	0.16	0.00	-	1.04
		28	0.32	0.39	0.02	0.18	0.14	0.00	-	1.05
		29	0.31	0.40	0.02	0.17	0.14	0.00	-	1.05
		30	0.17	0.76	.02	0.06	0.06	0.00	-	1.07
	C	1	0.00	-0.00	.00	1.03	0.00	0.00	-	1.03
		2	0.00	-0.00	.00	0.01	1.02	0.00	-	1.03
		3	0.00	-0.00	.00	0.00	0.01	1.04	-	1.04
		4	0.00	-0.00	.00	-0.00	0.00	0.01	-	0.00
		5	1.01	-0.00	.00	0.00	0.00	0.00	-	1.01
		6	0.01	1.00	.00	-0.00	0.00	0.00	-	1.01
		7	0.01	0.00	.98	0.00	0.00	0.00	-	0.99
		8	0.02	0.00	.95	0.01	0.01	0.00	-	0.98
		9	0.02	0.00	.94	0.01	0.01	0.00	-	0.98
		10	0.02	0.00	.93	0.01	0.01	0.00	-	0.98
		11	0.07	0.03	.80	0.04	0.04	0.00	-	0.98
		12	0.09	0.03	.10	0.06	0.04	0.00	-	0.33
		13	0.02	0.00	.01	0.01	0.01	0.96	-	1.01
		14	0.00	-0.00	.00	0.00	0.99	0.01	-	1.01
		15	0.00	0.00	.00	1.02	0.01	0.01	-	1.04
		16	0.00	0.00	.00	1.03	0.01	0.01	-	1.05
		17	0.00	0.00	.00	1.05	0.01	0.01	-	1.07
		18	0.00	0.00	.00	1.05	0.01	0.01	-	1.07
		19	0.01	0.00	.00	1.04	0.01	0.01	-	1.07
		20	1.03	0.01	.01	0.01	0.01	0.01	-	1.06
		21	1.02	0.01	.01	0.01	0.01	0.01	-	1.05
		22	1.03	0.01	.01	0.00	0.01	0.01	-	1.06
		23	1.03	0.01	.01	0.00	0.01	0.01	-	1.06
		24	1.03	0.01	.01	0.00	0.01	0.01	-	1.05
		25	0.39	0.16	.01	0.26	0.20	0.01	-	1.03
		26	0.41	0.17	.01	0.25	0.19	0.01	-	1.03
		27	0.40	0.17	.01	0.25	0.19	0.01	-	1.02
		28	0.42	0.16	.01	0.26	0.18	0.01	-	1.04
		29	0.42	0.15	.01	0.25	0.20	0.01	-	1.04
		30	0.42	0.17	.01	0.26	0.20	0.01	-	1.05
		31	0.40	0.17	.02	0.25	0.20	-0.00	-	1.03
		32	0.38	0.23	.02	0.23	0.19	-0.00	-	1.03
		33	0.36	0.25	.02	0.23	0.18	-0.00	-	1.03
		34	0.11	0.91	.02	0.01	0.02	-0.00	-	1.06
		35	0.11	0.91	.02	0.01	0.02	-0.00	-	1.06
		36	0.11	0.92	.02	0.01	0.02	-0.00	-	1.07
		37	0.11	0.91	.02	0.01	0.02	-0.01	-	1.06
		38	0.11	0.92	.05	0.01	0.02	-0.00	-	1.10
		39	0.12	0.86	.02	0.01	0.03	-0.01	-	1.03
		40	0.13	0.85	.02	0.02	0.04	-0.01	-	1.04
		41	0.17	0.74	.02	0.05	0.07	-0.01	-	1.03
		42	0.31	0.39	.02	0.16	0.14	-0.01	-	1.01
		43	0.35	0.28	.02	0.20	0.17	-0.01	-	1.02
		44	0.40	0.16	.02	0.22	0.22	-0.01	-	1.01
		45	0.42	0.10	.02	0.26	0.21	-0.01	-	1.00
		46	0.42	0.10	.02	0.25	0.20	-0.01	-	0.98
		47	0.02	0.02	.02	-0.03	1.01	-0.01	-	1.03
		48	0.01	0.03	.02	-0.03	1.02	-0.01	-	1.04

FLOW AND SEAL TEST PARAMETERS FOR TEST 103 ON 4/01/91

Parameter	LOCATION						
	Seal 1	Seal 2	Seal 3	Seal 4	Forward	Inner	Aft
Ω, Rpm	1000	1000	1000	1000	1000	1000	1000
P, psia	58.11	57.75	57.26	56.97	57.07	57.27	57.16
T, °R	512	513	515	515	515	515	519
Rho, lb/(ft^3)	0.306	0.304	0.300	0.299	0.299	0.300	0.297
Emdot, lb/sec	-0.085	-0.049	0.210	0.177	0.146	0.057	0.067
μ, lb/(ft sec)	1.18E-05	1.18E-05	1.18E-05	1.18E-05	1.18E-05	1.18E-05	1.19E-05
Ro, in	9.12	9.12	9.12	9.12	9.12	9.12	9.12
Vo, ft/sec	79.602	79.602	79.602	79.602	79.602	79.602	79.602
Vφ, ft/sec	146.518	0	108.942	0	-	-	-
Vz, ft/sec	48.866	48.212	39.538	46.537	-	-	-
Qo, psi	0.209	0.209	0.209	0.209	0.209	0.209	0.209
δp/q	0	-1.737	-4.068	-5.439	-4.958	-4.033	-4.527
Vφ/Vo	1.841	0	1.369	0	-	-	-
Vz/Vo	0.614	0.606	0.497	0.585	-	-	-
Reto	1.57E+06	1.57E+06	1.57E+06	1.57E+06	1.57E+06	1.57E+06	1.57E+06
Rer	-1504	-875	3720	3124	2588	1004	1175
Rer/(Ret^0.8)	-0.017	-0.010	0.041	0.034	0.029	0.011	0.013
Mφ	0.132	0	0.098	0	-	-	-
Coolant Gas	-	-	-	-	Air	Air	Air

GAS SOURCE CONCENTRATION

TEST	-	PORT	φ12	φ13	φ14	φ01	φ03	φ05	φ07	TOTAL
103	A	1	0.00	1.03	0.00	0.00	0.00	-	-	1.04
		2	-0.00	1.03	0.00	0.00	0.00	-	-	1.04
		3	-0.00	1.04	0.00	0.00	0.00	-	-	1.05
		4	0.00	0.96	0.00	0.01	0.00	-	-	0.97
		5	-0.00	0.95	0.00	0.01	0.01	-	-	0.96
		6	0.01	0.93	0.00	0.02	0.01	-	-	0.96
		7	0.02	0.90	0.00	0.02	0.01	-	-	0.95
		8	0.13	0.73	0.00	0.07	0.02	-	-	0.96
		9	0.31	0.45	0.00	0.18	0.04	-	-	0.98
		10	0.52	0.01	0.00	0.35	0.12	-	-	1.00
		11	-	-	-	-	-	-	-	-
		12	0.69	0.01	-0.00	0.34	0.01	-	-	1.05
		13	0.65	0.01	0.00	0.37	0.01	-	-	1.03
		14	0.57	0.01	0.00	0.45	0.01	-	-	1.03
		15	0.68	0.01	0.00	0.37	0.01	-	-	1.06
		16	0.74	0.01	0.00	0.28	0.01	-	-	1.03
		17	0.67	0.01	0.00	0.34	0.01	-	-	1.03
		18	0.67	0.01	-0.00	0.36	0.01	-	-	1.04
		19	-	-	-	-	-	-	-	-
		20	0.53	0.01	0.00	0.49	0.01	-	-	1.05
		21	0.81	0.01	0.00	0.24	0.01	-	-	1.07
		22	0.97	0.01	0.00	0.09	0.01	-	-	1.08
		23	0.17	0.01	0.00	0.85	0.01	-	-	1.03
		24	1.05	0.01	0.00	0.01	0.01	-	-	1.08
		25	1.06	0.01	0.00	0.01	0.01	-	-	1.08
		26	1.10	0.01	-0.00	0.01	0.01	-	-	1.12
		27	1.10	0.01	0.00	0.01	0.01	-	-	1.13
		28	1.10	0.01	0.00	0.01	0.01	-	-	1.12
		29	1.09	0.01	0.00	0.01	0.01	-	-	1.11
		30	1.08	0.01	0.00	0.01	0.01	-	-	1.11
		31	1.09	0.01	-0.00	0.01	0.01	-	-	1.11
		32	1.08	0.01	-0.00	0.01	0.01	-	-	1.11
		33	1.08	0.01	0.00	0.01	0.01	-	-	1.11
		34	0.00	0.92	-0.00	0.01	0.01	-	-	0.94
		35	-0.00	0.91	0.00	0.01	0.01	-	-	0.93
		36	-0.00	0.93	0.00	0.01	0.01	-	-	0.94
		37	-0.00	0.92	0.00	0.01	0.01	-	-	0.94
		38	-0.00	0.92	0.00	0.01	0.01	-	-	0.94
		39	-0.00	0.89	0.00	0.01	0.01	-	-	0.91
	B	1	0.01	0.01	0.99	0.01	0.01	-	-	1.04
		2	0.01	0.01	0.99	0.01	0.01	-	-	1.04
		3	0.01	0.02	0.97	0.02	0.01	-	-	1.02
		4	0.01	0.02	1.02	0.01	0.01	-	-	1.08

GAS SOURCE CONCENTRATION (Cont.)

TEST	-	PORT	ϕ12	ϕ13	ϕ14	ϕ01	ϕ03	ϕ05	ϕ07	TOTAL
103	B	5	0.00	0.02	1.02	0.02	0.01	-	-	1.06
		6	0.00	0.02	1.00	0.02	0.01	-	-	1.05
		7	0.00	0.02	1.01	0.02	0.01	-	-	1.05
		8	0.00	0.02	1.00	0.02	0.01	-	-	1.05
		9	0.00	0.02	0.99	0.02	0.02	-	-	1.04
		10	0.41	0.21	0.07	0.23	0.09	-	-	1.01
		11	0.43	0.21	0.08	0.24	0.09	-	-	1.04
		12	0.44	0.22	0.06	0.25	0.09	-	-	1.04
		13	0.44	0.23	0.02	0.25	0.09	-	-	1.03
		14	0.44	0.23	0.02	0.26	0.09	-	-	1.04
		15	0.44	0.23	0.02	0.26	0.10	-	-	1.05
		16	0.45	0.23	0.02	0.25	0.09	-	-	1.04
		17	0.44	0.23	0.02	0.25	0.10	-	-	1.04
		18	0.45	0.24	0.02	0.26	0.10	-	-	1.05
		19	0.47	0.23	0.02	0.26	0.10	-	-	1.06
		20	0.46	0.23	0.02	0.26	0.09	-	-	1.06
		21	0.45	0.23	0.02	0.26	0.09	-	-	1.05
		22	0.40	0.31	0.02	0.23	0.09	-	-	1.05
		23	0.45	0.22	0.02	0.26	0.10	-	-	1.05
		24	0.44	0.24	0.02	0.26	0.09	-	-	1.04
		25	0.42	0.26	0.01	0.24	0.09	-	-	1.03
		26	0.41	0.30	0.02	0.23	0.09	-	-	1.04
		27	0.38	0.34	0.02	0.22	0.08	-	-	1.04
		28	0.34	0.40	0.02	0.20	0.08	-	-	1.03
		29	0.34	0.41	0.02	0.19	0.08	-	-	1.03
		30	0.10	0.80	0.02	0.07	0.04	-	-	1.01
	C	1	0.00	0.00	0.00	1.01	0.01	-	-	1.03
		2	-0.00	0.00	0.00	0.01	0.97	-	-	0.98
		3	-0.01	0.00	0.00	0.01	0.01	-	-	0.01
		4	-0.01	0.00	0.00	0.00	0.01	-	-	0.01
		5	1.03	0.00	0.00	0.01	0.01	-	-	1.05
		6	-0.01	0.95	0.00	0.01	0.00	-	-	0.95
		7	-0.01	0.01	0.96	0.01	0.01	-	-	0.97
		8	-0.00	0.01	0.94	0.01	0.01	-	-	0.96
		9	-0.00	0.01	0.93	0.01	0.01	-	-	0.96
		10	-0.00	0.01	0.87	0.01	0.01	-	-	0.90
		11	0.06	0.04	0.84	0.04	0.02	-	-	1.00
		12	0.07	0.04	0.11	0.05	0.02	-	-	0.29
		13	0.00	0.01	0.00	0.02	0.01	-	-	0.04
		14	-0.01	0.00	0.00	0.01	0.96	-	-	0.96
		15	-0.01	0.00	0.00	1.03	0.01	-	-	1.03
		16	-0.01	0.00	0.00	1.03	0.01	-	-	1.03
		17	-0.01	0.00	0.00	1.02	0.01	-	-	1.03
		18	-0.01	0.00	0.00	1.02	0.01	-	-	1.03
		19	-0.00	0.00	0.00	1.01	0.01	-	-	1.02
		20	1.07	0.00	0.00	0.02	0.01	-	-	1.09
		21	1.06	0.00	0.00	0.01	0.01	-	-	1.09
		22	1.06	0.00	0.00	0.01	0.01	-	-	1.08
		23	1.06	0.01	0.00	0.01	0.01	-	-	1.09
		24	1.05	0.00	0.00	0.01	0.01	-	-	1.08
		25	0.47	0.20	0.00	0.26	0.10	-	-	1.02
		26	0.50	0.20	0.00	0.26	0.08	-	-	1.04
		27	0.49	0.20	0.00	0.27	0.08	-	-	1.04
		28	0.49	0.19	0.00	0.27	0.08	-	-	1.04
		29	0.49	0.19	0.00	0.26	0.09	-	-	1.03
		30	0.49	0.20	0.00	0.26	0.09	-	-	1.04
		31	0.47	0.21	0.01	0.26	0.09	-	-	1.04
		32	0.43	0.25	0.01	0.25	0.10	-	-	1.03
		33	0.42	0.27	0.01	0.24	0.09	-	-	1.03
		34	0.01	0.92	0.01	0.02	0.02	-	-	0.99
		35	0.01	0.93	0.01	0.02	0.02	-	-	0.98
		36	0.00	0.93	0.01	0.02	0.02	-	-	0.98
		37	0.01	0.93	0.01	0.02	0.02	-	-	0.99
		38	0.01	0.92	0.02	0.02	0.02	-	-	0.99
		39	0.04	0.85	0.01	0.04	0.02	-	-	0.96
		40	0.05	0.82	0.01	0.04	0.03	-	-	0.96
		41	0.13	0.69	0.01	0.08	0.04	-	-	0.96
		42	0.35	0.39	0.01	0.19	0.07	-	-	1.01
		43	0.41	0.30	0.01	0.22	0.08	-	-	1.02
		44	0.49	0.18	0.01	0.25	0.11	-	-	1.05
		45	0.57	0.10	0.01	0.31	0.11	-	-	1.10
		46	0.53	0.12	0.02	0.30	0.10	-	-	1.07
		47	0.34	0.02	0.02	0.21	0.49	-	-	1.08
		48	0.02	0.02	0.01	0.03	0.94	-	-	1.01

FLOW AND SEAL TEST PARAMETERS FOR TEST 104 ON 3/28/91

Parameter	LOCATION						
	Seal 1	Seal 2	Seal 3	Seal 4	Forward	Inner	Aft
Ω, Rpm	1003	1003	1003	1003	1003	1003	1003
P, psia	59.81	59.50	58.97	58.75	59.12	59.38	59.34
T, °R	515	515	518	518	519	518	520
Rho, lb/(ft^3)	0.313	0.312	0.307	0.306	0.307	0.309	0.308
Emdot, lb/sec	-0.112	-0.048	0.250	0.205	0.142	0.074	0.130
μ, lb/(ft sec)	1.18E-05	1.18E-05	1.19E-05	1.19E-05	1.19E-05	1.19E-05	1.19E-05
Ro, in	9.12	9.12	9.12	9.12	9.12	9.12	9.12
Vo, ft/sec	79.813	79.813	79.813	79.813	79.813	79.813	79.813
Vφ, ft/sec	146.686	0	108.499	0	-	-	-
Vz, ft/sec	48.923	48.109	39.377	46.957	-	-	-
Qo, psi	0.215	0.215	0.215	0.215	0.215	0.215	0.215
δp/q	0	-1.443	-3.940	-4.952	-3.216	-2.006	-2.210
Vφ/Vo	1.838	0	1.359	0	-	-	-
Vz/Vo	0.613	0.603	0.493	0.588	-	-	-
Reto	1.61E+06	1.61E+06	1.61E+06	1.61E+06	1.61E+06	1.61E+06	1.61E+06
Rer	-1985	-844	4407	3607	2501	1301	2282
Rer/(Ret^0.8)	-0.022	-0.009	0.048	0.039	0.027	0.014	0.025
Mφ	0.132	0	0.097	0	-	-	-
Coolant Gas	-	-	-	-	Air	Air	Air

GAS SOURCE CONCENTRATION

TEST	-	PORT	φ12	φ13	φ14	φ01	φ03	φ05	φ07	TOTAL
104	A	1	0.00	1.01	0.00	0.00	0.00	-	-	1.02
		2	0.01	1.02	0.00	0.00	0.00	-	-	1.03
		3	0.01	1.01	0.00	0.01	0.00	-	-	1.03
		4	0.01	1.01	0.00	0.01	0.00	-	-	1.03
		5	0.01	1.02	0.00	0.01	0.00	-	-	1.04
		6	0.02	1.00	0.00	0.01	0.00	-	-	1.03
		7	0.03	0.97	0.00	0.02	0.00	-	-	1.03
		8	0.18	0.71	0.00	0.12	0.00	-	-	1.00
		9	0.34	0.42	0.00	0.24	0.00	-	-	0.99
		10	0.51	0.02	0.00	0.37	0.00	-	-	0.90
		11	-	-	-	-	-	-	-	-
		12	0.60	0.03	0.00	0.36	0.00	-	-	0.98
		13	0.58	0.03	0.00	0.37	0.00	-	-	0.98
		14	0.50	0.02	0.01	0.45	0.00	-	-	0.98
		15	0.57	0.02	0.01	0.39	0.00	-	-	0.99
		16	0.66	0.03	0.01	0.28	0.00	-	-	0.97
		17	0.62	0.03	0.01	0.31	0.00	-	-	0.96
		18	0.58	0.03	0.01	0.34	0.00	-	-	0.95
		19	-	-	-	-	-	-	-	-
		20	0.47	0.03	0.01	0.48	0.00	-	-	0.98
		21	0.68	0.03	0.01	0.26	0.00	-	-	0.97
		22	0.82	0.03	0.01	0.10	0.00	-	-	0.95
		23	0.14	0.02	0.01	0.94	0.00	-	-	1.11
		24	0.89	0.03	0.01	0.01	0.00	-	-	0.94
		25	0.90	0.03	0.01	0.01	0.00	-	-	0.94
		26	0.86	0.06	0.01	0.01	0.00	-	-	0.93
		27	0.90	0.04	0.01	0.01	0.00	-	-	0.95
		28	0.91	0.03	0.01	0.01	0.00	-	-	0.95
		29	0.89	0.06	0.01	0.01	0.00	-	-	0.96
		30	0.89	0.04	0.01	0.01	0.00	-	-	0.94
		31	0.90	0.03	0.01	0.01	0.00	-	-	0.95
		32	0.90	0.03	0.01	0.01	0.00	-	-	0.95
		33	0.91	0.03	0.01	0.01	0.00	-	-	0.95
		34	0.01	1.03	0.01	0.01	0.00	-	-	1.05
		35	0.01	1.05	0.01	0.01	0.00	-	-	1.07
		36	0.01	1.04	0.01	0.01	0.00	-	-	1.06
		37	0.01	1.04	0.01	0.01	0.00	-	-	1.06
		38	0.01	1.05	0.01	0.01	0.00	-	-	1.07
		39	0.01	1.05	0.01	0.01	0.00	-	-	1.07
	B	1	0.01	0.01	1.01	0.01	0.01	-	-	1.06
		2	0.01	0.02	1.00	0.01	0.01	-	-	1.06
		3	0.01	0.01	1.00	0.01	0.01	-	-	1.05
		4	0.01	0.02	1.00	0.01	0.01	-	-	1.05

GAS SOURCE CONCENTRATION (Cont.)

TEST	-	PORT	φ12	φ13	φ14	φ01	φ03	φ05	φ07	TOTAL
104	B	5	0.01	0.02	1.03	0.01	0.01	-	-	1.08
		6	0.01	0.02	1.02	0.01	0.00	-	-	1.07
		7	0.01	0.02	1.01	0.01	0.00	-	-	1.06
		8	0.01	0.02	1.01	0.01	0.00	-	-	1.06
		9	0.01	0.02	1.00	0.01	0.00	-	-	1.05
		10	0.38	0.24	0.12	0.25	0.01	-	-	0.99
		11	0.35	0.22	0.16	0.24	0.01	-	-	0.98
		12	0.35	0.22	0.16	0.24	0.01	-	-	0.98
		13	0.39	0.25	0.08	0.27	-0.01	-	-	0.97
		14	0.41	0.26	0.01	0.28	0.53	-	-	1.49
		15	0.42	0.26	0.01	0.27	0.01	-	-	0.98
		16	0.41	0.27	0.01	0.26	0.98	-	-	1.93
		17	0.41	0.27	0.01	0.26	0.01	-	-	0.96
		18	0.41	0.26	0.01	0.25	0.01	-	-	0.95
		19	0.42	0.26	0.01	0.24	0.01	-	-	0.94
		20	0.39	0.26	0.01	0.28	-0.00	-	-	0.94
		21	0.40	0.26	0.01	0.30	0.54	-	-	1.51
		22	0.34	0.35	0.01	0.27	0.00	-	-	0.97
		23	0.40	0.26	0.01	0.30	0.00	-	-	0.96
		24	0.39	0.28	0.01	0.29	0.00	-	-	0.97
		25	0.37	0.30	0.01	0.29	0.00	-	-	0.98
		26	0.34	0.35	0.01	0.28	0.00	-	-	0.99
		27	0.33	0.40	0.01	0.26	0.00	-	-	1.00
		28	0.29	0.46	0.01	0.24	0.00	-	-	1.01
		29	0.29	0.47	0.01	0.23	0.00	-	-	1.00
		30	0.10	0.87	0.01	0.09	0.00	-	-	1.06
	C	1	0.01	0.01	0.01	1.02	0.00	-	-	1.04
		2	0.01	0.01	0.01	0.01	0.00	-	-	0.03
		3	0.01	0.01	0.01	0.01	0.00	-	-	0.03
		4	0.01	0.01	0.01	0.01	0.00	-	-	0.03
		5	0.99	0.01	0.01	0.01	0.00	-	-	1.02
		6	0.01	1.03	0.00	0.00	0.00	-	-	1.04
		7	0.01	0.02	1.00	0.01	0.00	-	-	1.03
		8	0.01	0.02	0.99	0.01	0.00	-	-	1.02
		9	0.01	0.02	0.98	0.01	0.00	-	-	1.01
		10	0.01	0.02	0.98	0.01	0.00	-	-	1.01
		11	0.01	0.02	0.97	0.01	0.00	-	-	1.00
		12	0.06	0.05	0.19	0.04	0.00	-	-	0.34
		13	0.02	0.03	0.01	0.02	0.00	-	-	0.07
		14	0.01	0.02	0.01	0.01	0.00	-	-	0.04
		15	0.00	0.02	0.01	0.97	0.00	-	-	1.00
		16	0.01	0.02	0.01	0.96	0.00	-	-	0.99
		17	0.01	0.02	0.01	0.92	0.00	-	-	0.95
		18	0.01	0.02	0.01	0.90	0.00	-	-	0.94
		19	0.01	0.02	0.01	0.85	0.00	-	-	0.89
		20	0.88	0.02	0.01	0.01	0.00	-	-	0.92
		21	0.89	0.03	0.01	0.01	0.00	-	-	0.94
		22	0.88	0.03	0.01	0.01	0.00	-	-	0.93
		23	0.89	0.03	0.01	0.01	0.00	-	-	0.93
		24	0.89	0.03	0.01	0.01	0.00	-	-	0.94
		25	0.40	0.24	0.01	0.32	0.00	-	-	0.97
		26	0.40	0.25	0.01	0.32	0.00	-	-	0.98
		27	0.41	0.25	0.01	0.32	0.00	-	-	0.98
		28	0.41	0.24	0.01	0.32	0.00	-	-	0.98
		29	0.42	0.23	0.01	0.32	0.00	-	-	0.97
		30	0.41	0.25	0.01	0.32	0.00	-	-	0.99
		31	0.41	0.24	0.01	0.33	0.00	-	-	0.99
		32	0.38	0.30	0.01	0.30	0.00	-	-	0.99
		33	0.37	0.32	0.01	0.29	0.00	-	-	0.99
		34	0.02	1.01	0.01	0.02	0.00	-	-	1.06
		35	0.02	1.02	0.01	0.02	0.00	-	-	1.07
		36	0.02	1.02	0.01	0.02	0.00	-	-	1.07
		37	0.02	1.02	0.02	0.02	0.00	-	-	1.08
		38	0.03	1.02	0.02	0.03	0.00	-	-	1.09
		39	0.04	0.96	0.02	0.04	0.00	-	-	1.05
		40	0.05	0.96	0.02	0.04	0.00	-	-	1.06
		41	0.10	0.85	0.02	0.09	0.00	-	-	1.05
		42	0.25	0.53	0.02	0.21	0.00	-	-	1.01
		43	0.32	0.40	0.02	0.27	0.00	-	-	1.01
		44	0.42	0.23	0.02	0.33	0.00	-	-	0.99
		45	0.45	0.13	0.02	0.38	0.00	-	-	0.98
		46	0.42	0.18	0.02	0.35	0.00	-	-	0.97
		47	0.39	0.04	0.02	0.36	0.00	-	-	0.80
		48	0.03	0.04	0.02	0.03	0.00	-	-	0.11

FLOW AND SEAL TEST PARAMETERS FOR TEST 105 ON 4/02/91

Parameter	LOCATION						
	Seal 1	Seal 2	Seal 3	Seal 4	Forward	Inner	Aft
Ω, Rpm	1001	1001	1001	1001	1001	1001	1001
P, psia	52.83	52.55	52.08	51.73	51.89	52.18	52.05
T, °R	510	510	510	510	514	514	515
Rho, lb/(ft^3)	0.280	0.278	0.275	0.274	0.273	0.274	0.273
Emdot, lb/sec	-0.084	-0.026	0.207	0.192	0.176	0.087	0.059
μ, lb/(ft sec)	1.17E-05	1.17E-05	1.18E-05	1.18E-05	1.18E-05	1.18E-05	1.18E-05
Ro, in	9.12	9.12	9.12	9.12	9.12	9.12	9.12
Vo, ft/sec	79.672	79.672	79.672	79.672	79.672	79.672	79.672
Vφ, ft/sec	156.039	0	114.980	0	-	-	-
Vz, ft/sec	51.454	50.568	41.258	48.647	-	-	-
Qo, psi	0.191	0.191	0.191	0.191	0.191	0.191	0.191
δp/q	0	-1.472	-3.917	-5.754	-4.948	-3.433	-4.067
Vφ/Vo	1.959	0	1.443	0	-	-	-
Vz/Vo	0.646	0.635	0.518	0.611	-	-	-
Reto	1.44E+06	1.44E+06	1.44E+06	1.44E+06	1.44E+06	1.44E+06	1.44E+06
Rer	-1496	-470	3687	3414	3117	1537	1038
Rer/(Ret^0.8)	-0.018	-0.006	0.044	0.040	0.037	0.018	0.012
Mφ	0.141	0	0.104	0	-	-	-
Coolant Gas	-	-	-	-	Air	Air	Air

GAS SOURCE CONCENTRATION

TEST	-	PORT	φ12	φ13	φ14	φ01	φ03	φ05	φ07	TOTAL
105	A	1	0.01	0.99	0.00	0.00	0.00	-	-	1.01
		2	0.01	0.99	0.00	0.00	0.00	-	-	1.01
		3	0.01	0.98	0.00	0.00	0.00	-	-	0.99
		4	0.01	1.00	0.00	0.01	0.00	-	-	1.02
		5	0.01	1.03	0.00	0.00	0.00	-	-	1.05
		6	0.02	0.99	0.00	0.01	0.00	-	-	1.03
		7	0.04	0.96	0.00	0.02	0.00	-	-	1.02
		8	0.22	0.69	0.00	0.09	0.01	-	-	1.00
		9	0.41	0.38	0.00	0.19	0.01	-	-	1.00
		10	0.59	0.00	0.00	0.34	0.06	-	-	0.99
		11	-	-	-	-	-	-	-	-
		12	0.67	0.00	0.00	0.31	0.00	-	-	0.99
		13	0.66	-0.00	0.00	0.33	0.00	-	-	0.99
		14	0.58	-0.01	0.00	0.40	0.00	-	-	0.98
		15	0.67	-0.01	0.00	0.33	0.00	-	-	1.00
		16	0.76	-0.01	0.00	0.23	0.00	-	-	0.99
		17	0.75	-0.01	0.00	0.27	0.00	-	-	1.01
		18	0.71	-0.02	0.00	0.31	0.00	-	-	1.01
		19	-	-	-	-	-	-	-	-
		20	0.56	-0.02	0.00	0.42	0.01	-	-	0.97
		21	0.80	-0.02	0.00	0.18	0.01	-	-	0.97
		22	0.93	-0.02	0.00	0.05	0.01	-	-	0.97
		23	0.20	-0.03	0.00	0.84	0.01	-	-	1.02
		24	1.01	-0.03	0.00	0.01	0.00	-	-	1.00
		25	1.01	-0.03	0.00	0.01	0.01	-	-	1.00
		26	0.99	0.02	0.00	0.01	0.01	-	-	1.02
		27	1.04	-0.01	0.00	0.01	0.01	-	-	1.04
		28	1.06	-0.03	0.00	0.01	0.01	-	-	1.05
		29	1.06	0.00	0.00	0.01	0.01	-	-	1.08
		30	1.06	-0.02	0.00	0.01	0.01	-	-	1.05
		31	1.12	-0.02	0.00	0.01	0.01	-	-	1.10
		32	1.09	-0.03	0.00	0.01	0.01	-	-	1.08
		33	1.08	-0.03	0.00	0.01	0.01	-	-	1.07
		34	0.03	0.75	0.00	0.01	0.01	-	-	0.79
		35	0.02	0.76	0.00	0.01	0.01	-	-	0.79
		36	0.02	0.76	0.00	0.01	0.01	-	-	0.79
		37	0.02	0.77	0.00	0.01	0.01	-	-	0.80
		38	0.02	0.77	0.00	0.01	0.01	-	-	0.80
		39	0.02	0.79	0.00	0.01	0.01	-	-	0.82
	B	1	0.01	0.01	1.03	0.01	0.01	-	-	1.07
		2	0.02	0.01	1.05	0.01	0.01	-	-	1.10
		3	0.02	0.02	1.03	0.02	0.01	-	-	1.09
		4	0.02	0.02	1.01	0.02	0.01	-	-	1.08

GAS SOURCE CONCENTRATION (Cont.)

TEST	-	PORT	φ12	φ13	φ14	φ01	φ03	φ05	φ07	TOTAL
105	B	5	0.03	0.02	1.01	0.02	0.01	-	-	1.07
		6	0.03	0.01	0.99	0.02	0.01	-	-	1.06
		7	0.03	0.02	0.97	0.02	0.01	-	-	1.05
		8	0.03	0.02	1.00	0.02	0.01	-	-	1.07
		9	0.03	0.01	1.03	0.02	0.01	-	-	1.09
		10	0.49	0.24	0.05	0.23	0.03	-	-	1.03
		11	0.50	0.26	0.02	0.23	0.03	-	-	1.04
		12	0.50	0.25	0.01	0.23	0.03	-	-	1.03
		13	0.51	0.25	0.01	0.24	0.03	-	-	1.03
		14	0.50	0.24	0.01	0.24	0.03	-	-	1.02
		15	0.50	0.24	0.01	0.24	0.03	-	-	1.02
		16	0.52	0.25	0.01	0.24	0.03	-	-	1.04
		17	0.53	0.25	0.01	0.24	0.03	-	-	1.05
		18	0.53	0.24	0.01	0.24	0.03	-	-	1.04
		19	0.52	0.23	0.01	0.24	0.03	-	-	1.03
		20	0.52	0.23	0.01	0.24	0.03	-	-	1.03
		21	0.52	0.23	0.01	0.23	0.03	-	-	1.03
		22	0.43	0.36	0.00	0.19	0.03	-	-	1.01
		23	0.53	0.24	0.00	0.23	0.03	-	-	1.03
		24	0.52	0.25	0.00	0.23	0.03	-	-	1.04
		25	0.50	0.28	0.00	0.22	0.03	-	-	1.04
		26	0.47	0.32	0.00	0.20	0.03	-	-	1.02
		27	0.44	0.37	0.00	0.19	0.03	-	-	1.03
		28	0.40	0.31	0.00	0.17	0.02	-	-	0.89
		29	0.39	0.31	0.00	0.17	0.02	-	-	0.88
		30	0.16	0.56	0.00	0.07	0.01	-	-	0.79
	C	1	0.01	0.00	0.00	0.51	0.01	-	-	0.52
		2	0.01	0.00	0.00	0.01	1.01	-	-	1.03
		3	0.01	0.00	0.00	0.01	0.01	-	-	0.02
		4	0.01	0.01	0.00	0.01	0.00	-	-	0.02
		5	1.01	0.00	0.00	0.00	0.00	-	-	1.02
		6	0.01	1.00	0.00	0.00	0.00	-	-	1.02
		7	0.01	0.01	0.00	0.01	0.00	-	-	0.03
		8	0.02	0.01	0.00	0.01	0.01	-	-	0.05
		9	0.03	0.01	0.00	0.01	0.00	-	-	0.05
		10	0.03	0.00	0.00	0.01	0.00	-	-	0.04
		11	0.09	0.05	0.00	0.04	0.01	-	-	0.19
		12	0.11	0.05	0.00	0.05	0.01	-	-	0.22
		13	0.03	-0.00	0.00	0.01	0.00	-	-	0.04
		14	0.02	-0.02	0.00	0.01	0.89	-	-	0.89
		15	0.01	-0.02	0.00	1.05	0.01	-	-	1.05
		16	0.01	-0.02	0.00	1.05	0.00	-	-	1.05
		17	0.01	-0.02	0.00	1.06	0.01	-	-	1.06
		18	0.01	-0.02	0.00	1.06	0.01	-	-	1.06
		19	0.02	-0.02	0.00	1.05	0.01	-	-	1.05
		20	0.97	-0.02	0.00	0.01	0.01	-	-	0.97
		21	0.97	-0.02	0.00	0.01	0.01	-	-	0.97
		22	0.97	-0.02	0.00	0.01	0.01	-	-	0.96
		23	1.00	-0.02	0.00	0.01	0.00	-	-	0.98
		24	1.01	-0.03	0.00	0.01	0.01	-	-	0.99
		25	0.51	0.23	0.00	0.23	0.03	-	-	1.01
		26	0.54	0.22	0.00	0.24	0.02	-	-	1.01
		27	0.55	0.21	0.00	0.24	0.02	-	-	1.02
		28	0.56	0.14	0.00	0.25	0.02	-	-	0.97
		29	0.55	0.14	0.00	0.23	0.03	-	-	0.96
		30	0.56	0.16	0.00	0.23	0.02	-	-	0.97
		31	0.60	0.14	0.00	0.25	0.03	-	-	1.01
		32	0.54	0.18	0.00	0.23	0.03	-	-	0.98
		33	0.52	0.21	0.00	0.21	0.03	-	-	0.97
		34	0.05	0.67	0.00	0.02	0.01	-	-	0.75
		35	0.05	0.68	0.00	0.02	0.01	-	-	0.75
		36	0.05	0.68	0.00	0.01	0.01	-	-	0.76
		37	0.06	0.69	0.00	0.01	0.01	-	-	0.77
		38	0.06	0.69	0.00	0.01	0.01	-	-	0.77
		39	0.08	0.69	0.00	0.02	0.01	-	-	0.79
		40	0.09	0.68	0.00	0.02	0.00	-	-	0.79
		41	0.16	0.62	0.00	0.05	0.01	-	-	0.83
		42	0.37	0.41	0.00	0.13	0.01	-	-	0.92
		43	0.48	0.31	0.00	0.18	0.01	-	-	0.98
		44	0.66	0.12	0.00	0.24	0.03	-	-	1.05
		45	0.74	0.04	0.00	0.30	0.02	-	-	1.10
		46	0.73	0.06	0.00	0.29	0.02	-	-	1.10
		47	0.77	-0.03	0.00	0.33	0.06	-	-	1.13
		48	0.12	-0.03	0.00	0.03	0.77	-	-	0.89

FLOW AND SEAL TEST PARAMETERS FOR TEST 201 ON 4/04/91

Parameter	LOCATION						
	Seal 1	Seal 2	Seal 3	Seal 4	Forward	Inner	Aft
Ω, Rpm	1502	1502	1502	1502	1502	1502	1502
P, psia	57.37	56.56	55.45	54.92	55.87	56.27	56.16
T, °R	507	507	510	510	511	511	511
Rho, lb/(ft^3)	0.306	0.301	0.293	0.291	0.295	0.298	0.296
Emdot, lb/sec	-0.210	-0.110	0.302	0.293	0.191	0.092	0.095
μ, lb/(ft sec)	1.17E-05	1.17E-05	1.17E-05	1.17E-05	1.18E-05	1.18E-05	1.18E-05
Ro, in	9.12	9.12	9.12	9.12	9.12	9.12	9.12
Vo, ft/sec	119.576	119.576	119.576	119.576	119.576	119.576	119.576
Vϕ, ft/sec	187.680	0	169.285	0	-	-	-
Vz, ft/sec	62.595	62.636	61.439	77.577	-	-	-
Qo, psi	0.471	0.471	0.471	0.471	0.471	0.471	0.471
δp/q	0	-1.726	-4.071	-5.190	-3.175	-2.337	-2.568
Vϕ/Vo	1.570	0	1.416	0	-	-	-
Vz/Vo	0.523	0.524	0.514	0.649	-	-	-
Reto	2.38E+06	2.38E+06	2.38E+06	2.38E+06	2.38E+06	2.38E+06	2.38E+06
Rer	-3769	-1977	5376	5225	3394	1645	1692
Rer/(Ret^0.8)	-0.030	-0.016	0.043	0.041	0.027	0.013	0.013
Mϕ	0.170	0	0.153	0	-	-	-
Coolant Gas	-	-	-	-	Air	Air	Air

GAS SOURCE CONCENTRATION

TEST	-	PORT	ϕ12	ϕ13	ϕ14	ϕ01	ϕ03	ϕ05	ϕ07	TOTAL
201	A	1	-0.00	1.02	-0.00	-0.01	-0.00	-	-	1.00
		2	-0.00	1.02	-0.00	-0.02	0.00	-	-	1.00
		3	0.00	1.01	-0.00	-0.02	0.00	-	-	0.99
		4	0.00	1.02	-0.00	-0.02	0.00	-	-	1.00
		5	0.01	1.01	-0.00	-0.03	0.01	-	-	0.99
		6	0.01	1.00	-0.01	-0.03	0.01	-	-	1.00
		7	0.02	1.00	-0.01	-0.02	0.01	-	-	1.01
		8	0.13	0.73	-0.01	0.07	0.05	-	-	0.97
		9	0.29	0.40	-0.01	0.22	0.08	-	-	0.98
		10	0.38	0.00	-0.01	0.32	0.28	-	-	0.97
		11	-	-	-	-	-	-	-	-
		12	0.58	0.01	-0.01	0.40	0.00	-	-	0.98
		13	0.59	0.01	-0.01	0.39	0.00	-	-	0.98
		14	0.47	0.01	-0.01	0.51	0.00	-	-	0.98
		15	0.50	0.01	-0.01	0.48	0.00	-	-	0.98
		16	0.61	0.01	-0.01	0.38	0.00	-	-	0.99
		17	0.65	0.01	-0.00	0.33	0.00	-	-	0.99
		18	0.57	0.01	-0.01	0.46	0.00	-	-	1.04
		19	-	-	-	-	-	-	-	-
		20	0.53	0.01	-0.01	0.45	0.00	-	-	0.99
		21	0.79	0.01	-0.00	0.21	0.00	-	-	1.01
		22	0.93	0.01	-0.01	0.08	0.00	-	-	1.02
		23	0.09	0.01	-0.00	0.93	0.00	-	-	1.02
		24	1.04	0.00	-0.00	-0.03	0.00	-	-	1.01
		25	1.06	0.01	-0.00	-0.03	0.00	-	-	1.03
		26	1.05	0.02	-0.01	-0.04	0.00	-	-	1.03
		27	1.06	0.01	-0.00	-0.03	0.01	-	-	1.04
		28	1.06	0.01	-0.00	-0.03	0.01	-	-	1.04
		29	1.06	0.01	-0.00	-0.03	0.01	-	-	1.05
		30	1.05	0.01	-0.00	-0.03	0.01	-	-	1.04
		31	1.06	0.01	-0.00	-0.03	0.01	-	-	1.04
		32	1.07	0.00	-0.01	-0.03	0.01	-	-	1.05
		33	1.07	0.00	-0.01	-0.02	0.01	-	-	1.05
		34	0.00	1.09	-0.01	-0.02	0.01	-	-	1.07
		35	0.00	1.09	-0.00	-0.02	0.01	-	-	1.07
		36	0.00	1.10	-0.00	-0.02	0.01	-	-	1.08
		37	0.00	1.11	-0.01	-0.02	0.01	-	-	1.09
		38	0.00	1.11	-0.01	-0.02	0.01	-	-	1.09
		39	0.00	1.10	-0.01	-0.02	0.01	-	-	1.09
	B	1	0.01	0.01	1.02	-0.00	0.01	-	-	1.04
		2	0.01	0.01	1.03	-0.01	0.01	-	-	1.04
		3	0.01	0.01	1.03	-0.01	0.01	-	-	1.05
		4	0.01	0.01	1.02	-0.01	0.01	-	-	1.03

GAS SOURCE CONCENTRATION (Cont.)

TEST	-	PORT	φ12	φ13	φ14	φ01	φ03	φ05	φ07	TOTAL
201	B	5	0.01	0.01	1.03	-0.02	0.01	-	-	1.04
		6	0.01	0.01	1.02	-0.03	0.01	-	-	1.03
		7	0.01	0.01	1.03	-0.03	0.01	-	-	1.03
		8	0.01	0.01	1.04	-0.03	0.01	-	-	1.04
		9	0.01	0.01	1.05	-0.03	0.01	-	-	1.05
		10	0.34	0.17	0.06	0.26	0.18	-	-	1.01
		11	0.35	0.19	0.04	0.26	0.18	-	-	1.01
		12	0.36	0.19	0.01	0.27	0.19	-	-	1.01
		13	0.36	0.19	0.01	0.27	0.18	-	-	1.00
		14	0.36	0.19	0.01	0.27	0.18	-	-	1.01
		15	0.36	0.19	0.01	0.27	0.19	-	-	1.01
		16	0.36	0.19	0.01	0.27	0.19	-	-	1.02
		17	0.36	0.19	0.01	0.27	0.17	-	-	1.00
		18	0.36	0.19	0.01	0.28	0.18	-	-	1.02
		19	0.37	0.19	0.01	0.27	0.17	-	-	1.00
		20	0.37	0.19	0.01	0.27	0.17	-	-	1.01
		21	0.37	0.19	0.01	0.27	0.18	-	-	1.01
		22	0.30	0.33	0.01	0.22	0.15	-	-	1.00
		23	0.37	0.19	0.01	0.28	0.17	-	-	1.01
		24	0.36	0.21	0.01	0.27	0.17	-	-	1.02
		25	0.34	0.25	0.01	0.25	0.17	-	-	1.02
		26	0.31	0.32	0.01	0.23	0.16	-	-	1.02
		27	0.28	0.38	0.01	0.21	0.15	-	-	1.03
		28	0.25	0.45	0.01	0.19	0.14	-	-	1.03
		29	0.25	0.46	0.01	0.18	0.13	-	-	1.03
		30	0.08	0.87	0.01	0.04	0.05	-	-	1.05
	C	1	0.00	-0.00	-0.00	1.01	0.00	-	-	1.01
		2	-0.00	-0.00	-0.00	-0.02	1.01	-	-	0.99
		3	-0.00	-0.00	-0.00	-0.02	0.01	-	-	0.02
		4	-0.00	-0.00	-0.00	-0.03	0.00	-	-	0.03
		5	1.02	-0.00	-0.00	-0.03	0.00	-	-	0.99
		6	0.00	1.05	-0.01	-0.04	0.00	-	-	1.01
		7	0.00	0.00	1.03	-0.04	0.00	-	-	1.00
		8	0.01	0.00	1.01	-0.04	0.01	-	-	0.99
		9	0.01	0.00	1.02	-0.04	0.01	-	-	1.00
		10	0.01	0.00	1.02	-0.04	0.01	-	-	1.00
		11	0.07	0.04	0.84	0.02	0.04	-	-	0.99
		12	0.07	0.04	0.10	0.02	0.04	-	-	0.26
		13	0.02	0.01	-0.00	-0.03	0.01	-	-	0.00
		14	-0.00	0.00	-0.00	-0.05	1.04	-	-	0.99
		15	-0.00	0.00	-0.00	1.00	0.01	-	-	1.00
		16	-0.00	0.00	-0.00	1.01	0.00	-	-	1.01
		17	-0.00	0.00	-0.00	1.01	0.00	-	-	1.01
		18	-0.00	0.00	-0.00	1.01	0.00	-	-	1.01
		19	-0.00	0.00	-0.01	1.01	0.00	-	-	1.00
		20	1.03	0.00	-0.01	-0.02	0.00	-	-	1.00
		21	1.04	0.01	-0.00	-0.03	0.00	-	-	1.01
		22	1.05	0.00	-0.01	-0.04	0.00	-	-	1.01
		23	1.05	0.01	-0.00	-0.03	0.00	-	-	1.02
		24	1.05	0.00	-0.00	-0.03	0.00	-	-	1.01
		25	0.36	0.18	-0.00	0.28	0.19	-	-	1.00
		26	0.37	0.18	-0.00	0.28	0.18	-	-	1.01
		27	0.37	0.18	-0.00	0.28	0.18	-	-	1.00
		28	0.38	0.17	-0.00	0.29	0.18	-	-	1.01
		29	0.38	0.16	-0.00	0.28	0.20	-	-	1.01
		30	0.38	0.17	-0.00	0.28	0.18	-	-	1.00
		31	0.37	0.16	0.00	0.28	0.18	-	-	1.00
		32	0.34	0.24	0.00	0.26	0.17	-	-	1.01
		33	0.32	0.26	0.00	0.25	0.16	-	-	1.00
		34	0.01	1.04	0.00	-0.01	0.02	-	-	1.06
		35	0.01	1.05	0.00	-0.01	0.01	-	-	1.06
		36	0.01	1.05	0.00	-0.01	0.01	-	-	1.07
		37	0.01	1.05	0.00	-0.01	0.01	-	-	1.06
		38	0.01	1.04	0.00	-0.01	0.01	-	-	1.06
		39	0.03	0.99	0.00	0.01	0.02	-	-	1.06
		40	0.04	0.97	0.00	0.02	0.03	-	-	1.06
		41	0.08	0.86	0.00	0.05	0.05	-	-	1.05
		42	0.23	0.50	0.00	0.17	0.10	-	-	1.01
		43	0.29	0.36	0.00	0.22	0.13	-	-	1.01
		44	0.38	0.15	0.00	0.29	0.18	-	-	1.00
		45	0.40	0.08	0.00	0.34	0.17	-	-	0.99
		46	0.40	0.08	0.01	0.33	0.17	-	-	0.98
		47	0.02	0.01	0.00	0.01	0.91	-	-	0.94
		48	0.01	0.01	0.00	-0.00	0.94	-	-	0.96

FLOW AND SEAL TEST PARAMETERS FOR TEST 202 ON 4/09/91

Parameter	Seal 1	Seal 2	Seal 3	Seal 4	Forward	Inner	Aft
	LOCATION						
Ω, Rpm	1502	1502	1502	1502	1502	1502	1502
P, psia	57.24	56.48	55.49	54.93	55.89	56.03	55.93
T, °R	530	530	530	530	530	530	532
Rho, lb/(ft^3)	0.292	0.288	0.283	0.280	0.284	0.285	0.284
Emdot, lb/sec	-0.224	-0.154	0.257	0.271	0.115	0.057	0.087
μ, lb/(ft sec)	1.21E-05	1.21E-05	1.21E-05	1.21E-05	1.21E-05	1.21E-05	1.21E-05
Ro, in	9.12	9.12	9.12	9.12	9.12	9.12	9.12
Vo, ft/sec	119.518	119.518	119.518	119.518	119.518	119.518	119.518
Vϕ, ft/sec	200.943	0	178.610	0	-	-	-
Vz, ft/sec	67.019	65.629	64.823	81.149	-	-	-
Qo, psi	0.449	0.449	0.449	0.449	0.449	0.449	0.449
δp/q	0	-1.691	-3.908	-5.149	-3.007	-2.697	-2.916
Vϕ/Vo	1.681	0	1.494	0	-	-	-
Vz/Vo	0.561	0.549	0.542	0.679	-	-	-
Reto	2.19E+06	2.19E+06	2.19E+06	2.19E+06	2.19E+06	2.19E+06	2.19E+06
Rer	-3660	-2659	4444	4692	1984	994	1495
Rer/(Ret^0.8)	-0.031	-0.023	0.038	0.040	0.017	0.008	0.013
Mϕ	0.178	0	0.158	0	-	-	-
Coolant Gas	-	-	-	-	Air	Air	Air

GAS SOURCE CONCENTRATION

TEST	-	PORT	ϕ12	ϕ13	ϕ14	ϕ01	ϕ03	ϕ05	ϕ07	TOTAL
202	A	1	0.02	0.99	0.00	0.00	0.00	-	-	1.01
		2	0.00	1.00	0.00	0.00	0.00	-	-	1.01
		3	0.02	0.94	0.00	0.03	0.02	-	-	1.01
		4	0.03	0.90	0.01	0.04	0.04	-	-	1.02
		5	0.03	0.90	0.01	0.05	0.04	-	-	1.02
		6	0.04	0.87	0.01	0.06	0.05	-	-	1.02
		7	0.05	0.86	0.01	0.07	0.06	-	-	1.04
		8	0.09	0.67	0.01	0.13	0.11	-	-	1.01
		9	0.14	0.45	0.01	0.22	0.17	-	-	0.98
		10	0.07	0.01	0.01	0.11	0.79	-	-	0.99
		11	-	-	-	-	-	-	-	-
		12	0.42	0.03	0.01	0.55	0.01	-	-	1.01
		13	0.45	0.02	0.01	0.54	-0.00	-	-	1.02
		14	0.37	0.02	0.01	0.63	-0.01	-	-	1.02
		15	0.38	0.02	0.01	0.60	-0.01	-	-	1.00
		16	0.42	0.02	0.01	0.58	-0.02	-	-	1.01
		17	0.43	0.02	0.02	0.54	-0.03	-	-	0.98
		18	0.34	0.02	0.02	0.64	-0.04	-	-	0.99
		19	-	-	-	-	-	-	-	-
		20	0.41	0.02	0.02	0.57	-0.04	-	-	0.99
		21	0.64	0.02	0.02	0.37	-0.04	-	-	1.01
		22	0.75	0.02	0.02	0.25	-0.05	-	-	1.00
		23	0.09	0.02	0.02	0.93	-0.05	-	-	1.01
		24	0.96	0.02	0.02	0.09	-0.05	-	-	1.04
		25	1.05	0.02	0.02	0.01	-0.05	-	-	1.05
		26	1.05	0.03	0.02	0.01	-0.06	-	-	1.05
		27	1.06	0.02	0.02	0.01	-0.06	-	-	1.05
		28	0.98	0.02	0.02	0.01	-0.06	-	-	0.96
		29	0.97	0.02	0.02	0.01	-0.06	-	-	0.96
		30	0.98	0.02	0.02	0.01	-0.06	-	-	0.97
		31	0.99	0.02	0.02	0.01	-0.06	-	-	0.98
		32	0.99	0.02	0.02	0.01	-0.06	-	-	0.98
		33	1.00	0.02	0.02	0.01	-0.06	-	-	0.99
		34	0.02	0.95	0.02	0.01	-0.06	-	-	0.94
		35	0.01	0.96	0.02	0.01	-0.06	-	-	0.94
		36	0.01	0.96	0.02	0.01	-0.06	-	-	0.95
		37	0.01	0.97	0.03	0.01	-0.06	-	-	0.96
		38	0.01	0.97	0.03	0.01	-0.05	-	-	0.96
		39	0.01	0.98	0.03	0.01	-0.05	-	-	0.97
	B	1	0.01	0.01	1.00	0.01	0.01	-	-	1.05
		2	0.01	0.01	1.00	0.01	0.02	-	-	1.05
		3	0.01	0.01	0.99	0.02	0.02	-	-	1.05
		4	0.01	0.01	0.98	0.02	0.02	-	-	1.04

GAS SOURCE CONCENTRATION (Cont.)

TEST	-	PORT	ϕ12	ϕ13	ϕ14	ϕ01	ϕ03	ϕ05	ϕ07	TOTAL
202	B	5	0.01	0.02	0.99	0.02	0.02	-	-	1.06
		6	0.01	0.02	0.99	0.02	0.02	-	-	1.06
		7	0.01	0.02	0.98	0.02	0.02	-	-	1.06
		8	0.02	0.02	0.98	0.02	0.02	-	-	1.06
		9	0.02	0.02	0.98	0.02	0.02	-	-	1.06
		10	0.21	0.12	0.06	0.34	0.30	-	-	1.03
		11	0.21	0.12	0.06	0.33	0.29	-	-	1.01
		12	0.22	0.13	0.02	0.33	0.30	-	-	1.01
		13	0.23	0.13	0.02	0.35	0.29	-	-	1.01
		14	0.23	0.13	0.02	0.35	0.30	-	-	1.02
		15	0.23	0.13	0.02	0.33	0.29	-	-	1.00
		16	0.23	0.13	0.02	0.35	0.28	-	-	1.01
		17	0.23	0.13	0.02	0.34	0.28	-	-	1.00
		18	0.23	0.13	0.02	0.34	0.27	-	-	1.00
		19	0.23	0.13	0.02	0.34	0.27	-	-	0.99
		20	0.23	0.13	0.02	0.34	0.27	-	-	0.99
		21	0.23	0.13	0.02	0.34	0.26	-	-	0.99
		22	0.22	0.21	0.03	0.30	0.23	-	-	0.98
		23	0.24	0.12	0.03	0.33	0.26	-	-	0.98
		24	0.23	0.14	0.03	0.34	0.25	-	-	0.99
		25	0.23	0.17	0.03	0.29	0.23	-	-	0.95
		26	0.22	0.22	0.03	0.29	0.22	-	-	0.97
		27	0.18	0.26	0.03	0.29	0.20	-	-	0.95
		28	0.17	0.31	0.03	0.27	0.18	-	-	0.96
		29	0.18	0.32	0.03	0.25	0.18	-	-	0.95
		30	0.06	0.77	0.03	0.08	0.01	-	-	0.95
	C	1	0.00	0.01	0.00	1.01	0.01	-	-	1.03
		2	0.00	0.01	0.01	0.01	0.99	-	-	1.01
		3	0.00	0.01	0.01	0.00	0.01	-	-	0.02
		4	0.00	0.01	0.01	0.00	0.00	-	-	0.02
		5	1.03	0.01	0.01	0.00	0.00	-	-	1.06
		6	0.01	1.03	0.01	0.00	0.00	-	-	1.04
		7	0.01	0.01	0.99	0.00	0.01	-	-	1.01
		8	0.01	0.01	0.96	0.01	0.01	-	-	1.00
		9	0.01	0.01	0.95	0.01	0.01	-	-	1.00
		10	0.01	0.01	0.95	0.01	0.02	-	-	1.01
		11	0.05	0.03	0.77	0.07	0.07	-	-	0.99
		12	0.05	0.03	0.11	0.07	0.06	-	-	0.31
		13	0.02	0.02	0.01	0.02	0.01	-	-	0.08
		14	0.01	0.01	0.02	0.00	0.95	-	-	0.99
		15	0.01	0.01	0.02	1.02	-0.02	-	-	1.03
		16	0.01	0.01	0.02	1.01	-0.03	-	-	1.01
		17	0.01	0.01	0.02	0.99	-0.03	-	-	0.99
		18	0.01	0.01	0.02	0.99	-0.04	-	-	1.00
		19	0.01	0.01	0.02	1.00	-0.04	-	-	1.00
		20	0.73	0.01	0.02	0.28	-0.04	-	-	1.00
		21	1.01	0.02	0.02	0.04	-0.04	-	-	1.03
		22	1.02	0.02	0.02	0.02	-0.05	-	-	1.03
		23	1.04	0.02	0.02	0.01	-0.05	-	-	1.03
		24	1.05	0.02	0.02	0.01	-0.05	-	-	1.04
		25	0.24	0.11	0.02	0.33	0.25	-	-	0.96
		26	0.25	0.12	0.02	0.35	0.24	-	-	0.98
		27	0.23	0.12	0.02	0.34	0.24	-	-	0.96
		28	0.97	0.11	0.02	0.37	0.24	-	-	1.71
		29	0.23	0.11	0.02	0.33	0.25	-	-	0.95
		30	0.23	0.11	0.02	0.34	0.25	-	-	0.95
		31	0.23	0.11	0.03	0.33	0.25	-	-	0.95
		32	0.21	0.16	0.03	0.32	0.23	-	-	0.96
		33	0.21	0.19	0.03	0.31	0.23	-	-	0.96
		34	0.02	0.94	0.03	0.02	-0.05	-	-	0.96
		35	0.02	0.93	0.03	0.02	-0.05	-	-	0.94
		36	0.02	0.94	0.03	0.02	-0.05	-	-	0.95
		37	0.02	0.94	0.03	0.02	-0.04	-	-	0.95
		38	0.02	0.93	0.03	0.01	-0.04	-	-	0.95
		39	0.07	0.71	0.03	0.10	0.04	-	-	0.95
		40	0.09	0.67	0.03	0.12	0.06	-	-	0.96
		41	0.15	0.43	0.03	0.21	0.14	-	-	0.95
		42	0.22	0.18	0.03	0.31	0.22	-	-	0.96
		43	0.23	0.14	0.03	0.34	0.24	-	-	0.98
		44	0.24	0.12	0.03	0.32	0.28	-	-	0.98
		45	0.24	0.08	0.03	0.39	0.26	-	-	0.99
		46	0.23	0.08	0.03	0.39	0.25	-	-	0.99
		47	0.01	0.03	0.03	0.03	0.88	-	-	0.99
		48	0.01	0.03	0.03	0.04	0.89	-	-	0.99

FLOW AND SEAL TEST PARAMETERS FOR TEST 203 ON 4/08/91

Parameter	LOCATION						
	Seal 1	Seal 2	Seal 3	Seal 4	Forward	Inner	Aft
Ω, Rpm	1500	1500	1500	1500	1500	1500	1500
P, psia	58.50	57.73	56.64	55.99	56.95	57.29	57.22
T, °R	533	532	531	531	531	531	530
Rho, lb/(ft^3)	0.296	0.293	0.288	0.284	0.290	0.291	0.291
Emdot, lb/sec	-0.178	-0.123	0.286	0.309	0.196	0.096	0.081
μ, lb/(ft sec)	1.21E-05	1.21E-05	1.21E-05	1.21E-05	1.21E-05	1.21E-05	1.21E-05
Ro, in	9.12	9.12	9.12	9.12	9.12	9.12	9.12
Vo, ft/sec	119.405	119.405	119.405	119.405	119.405	119.405	119.405
Vϕ, ft/sec	192.038	0	174.085	0	-	-	-
Vz, ft/sec	64.049	64.041	63.181	79.698	-	-	-
Qo, psi	0.456	0.456	0.456	0.456	0.456	0.456	0.456
δp/q	0	-1.676	-4.069	-5.508	-3.393	-2.655	-2.789
Vϕ/Vo	1.608	0	1.458	0	-	-	-
Vz/Vo	0.536	0.536	0.529	0.667	-	-	-
Reto	2.21E+06	2.21E+06	2.21E+06	2.21E+06	2.21E+06	2.21E+06	2.21E+06
Rer	-3066	-2123	4943	5341	3395	1650	1395
Rer/(Ret^0.8)	-0.026	-0.018	0.041	0.045	0.028	0.014	0.012
Mϕ	0.170	0	0.154	0	-	-	-
Coolant Gas	-	-	-	-	Air	Air	Air

GAS SOURCE CONCENTRATION

TEST	-	PORT	ϕ12	ϕ13	ϕ14	ϕ01	ϕ03	ϕ05	ϕ07	TOTAL
203	A	1	0.00	0.99	0.00	0.00	0.00	-	-	0.99
		2	0.00	1.00	0.00	0.00	0.00	-	-	1.00
		3	0.00	1.00	0.00	0.01	0.00	-	-	1.01
		4	0.01	1.00	0.00	0.01	0.01	-	-	1.02
		5	0.01	0.95	0.00	0.01	0.01	-	-	0.99
		6	0.02	0.94	0.01	0.02	0.01	-	-	0.99
		7	0.03	0.94	0.01	0.02	0.01	-	-	1.01
		8	0.09	0.78	0.01	0.08	0.05	-	-	1.01
		9	0.25	0.46	0.01	0.19	0.09	-	-	0.99
		10	0.30	0.00	0.01	0.23	0.47	-	-	1.01
		11	-	-	-	-	-	-	-	-
		12	0.61	0.01	0.01	0.39	0.00	-	-	1.03
		13	0.61	0.01	0.01	0.41	0.00	-	-	1.03
		14	0.51	0.01	0.01	0.52	0.00	-	-	1.04
		15	0.58	0.01	0.01	0.44	0.00	-	-	1.04
		16	0.70	0.01	0.01	0.32	0.00	-	-	1.05
		17	0.70	0.01	0.02	0.34	0.00	-	-	1.06
		18	0.65	0.01	0.02	0.40	0.01	-	-	1.08
		19	-	-	-	-	-	-	-	-
		20	0.52	0.01	0.02	0.52	0.01	-	-	1.08
		21	0.81	0.01	0.02	0.23	0.01	-	-	1.08
		22	0.96	0.01	0.02	0.11	0.01	-	-	1.10
		23	0.14	0.00	0.02	0.90	0.01	-	-	1.08
		24	1.05	0.01	0.02	0.02	0.01	-	-	1.11
		25	1.02	0.01	0.02	0.01	0.01	-	-	1.08
		26	1.03	0.02	0.03	0.01	0.01	-	-	1.10
		27	1.08	0.01	0.03	0.02	0.01	-	-	1.13
		28	1.07	0.01	0.03	0.02	0.01	-	-	1.13
		29	1.07	0.01	0.03	0.02	0.01	-	-	1.13
		30	1.08	0.01	0.03	0.02	0.01	-	-	1.14
		31	1.09	0.01	0.03	0.02	0.01	-	-	1.15
		32	1.09	0.01	0.03	0.02	0.01	-	-	1.15
		33	1.09	0.01	0.03	0.02	0.01	-	-	1.16
		34	0.01	1.02	0.03	0.02	0.01	-	-	1.08
		35	0.00	1.02	0.03	0.02	0.01	-	-	1.07
		36	0.00	1.02	0.03	0.02	0.01	-	-	1.08
		37	-0.00	1.03	0.04	0.02	0.01	-	-	1.08
		38	-0.01	1.02	0.04	0.02	0.01	-	-	1.06
		39	-0.02	0.98	0.04	0.02	0.01	-	-	1.01
	B	1	0.01	0.01	1.02	0.01	0.01	-	-	1.05
		2	0.01	0.01	1.01	0.01	0.01	-	-	1.05
		3	0.02	0.01	1.00	0.02	0.01	-	-	1.06
		4	0.02	0.01	1.00	0.02	0.01	-	-	1.06

TEST	-	PORT	φ12	φ13	φ14	φ01	φ03	φ05	φ07	TOTAL
203	B	5	0.02	0.01	1.00	0.02	0.01	-	-	1.06
		6	0.02	0.01	1.01	0.02	0.01	-	-	1.07
		7	0.02	0.01	1.01	0.02	0.01	-	-	1.08
		8	0.02	0.01	1.01	0.02	0.01	-	-	1.08
		9	0.03	0.01	1.02	0.02	0.01	-	-	1.09
		10	0.33	0.17	0.05	0.26	0.21	-	-	1.02
		11	0.34	0.18	0.03	0.26	0.21	-	-	1.02
		12	0.35	0.18	0.02	0.26	0.21	-	-	1.03
		13	0.35	0.18	0.02	0.25	0.21	-	-	1.01
		14	0.36	0.18	0.02	0.27	0.21	-	-	1.03
		15	0.36	0.18	0.02	0.26	0.21	-	-	1.04
		16	0.36	0.18	0.02	0.27	0.21	-	-	1.04
		17	0.36	0.18	0.02	0.26	0.21	-	-	1.04
		18	0.36	0.18	0.03	0.27	0.22	-	-	1.04
		19	0.36	0.18	0.03	0.27	0.22	-	-	1.06
		20	0.37	0.18	0.03	0.27	0.22	-	-	1.06
		21	0.36	0.18	0.03	0.26	0.21	-	-	1.04
		22	0.31	0.32	0.03	0.23	0.18	-	-	1.06
		23	0.37	0.18	0.03	0.26	0.21	-	-	1.06
		24	0.37	0.20	0.03	0.27	0.21	-	-	1.08
		25	0.33	0.24	0.03	0.24	0.19	-	-	1.04
		26	0.31	0.29	0.03	0.23	0.18	-	-	1.05
		27	0.30	0.34	0.04	0.21	0.17	-	-	1.06
		28	0.27	0.41	0.04	0.20	0.15	-	-	1.06
		29	0.26	0.42	0.04	0.20	0.14	-	-	1.07
		30	0.09	0.83	0.04	0.07	0.05	-	-	1.08
	C	1	0.00	0.00	0.00	1.02	0.01	-	-	1.03
		2	0.00	0.00	0.00	0.01	0.98	-	-	1.00
		3	0.00	0.00	0.00	0.01	0.01	-	-	0.02
		4	0.00	0.00	0.01	0.01	0.00	-	-	0.02
		5	1.00	0.00	0.01	0.01	0.00	-	-	1.01
		6	0.01	0.96	0.01	0.01	0.00	-	-	0.98
		7	0.01	0.01	1.02	0.01	0.00	-	-	1.05
		8	0.02	0.01	0.99	0.02	0.01	-	-	1.04
		9	0.02	0.01	0.99	0.02	0.01	-	-	1.05
		10	0.03	0.01	0.98	0.03	0.01	-	-	1.06
		11	0.09	0.04	0.79	0.08	0.05	-	-	1.05
		12	0.08	0.04	0.11	0.06	0.05	-	-	0.34
		13	0.03	0.01	0.01	0.03	0.01	-	-	0.09
		14	0.01	0.00	0.01	0.01	1.01	-	-	1.04
		15	0.01	0.00	0.01	1.04	0.01	-	-	1.07
		16	0.01	0.00	0.02	1.04	0.01	-	-	1.08
		17	0.01	0.00	0.02	1.04	0.01	-	-	1.08
		18	0.01	0.00	0.02	1.04	0.01	-	-	1.08
		19	0.02	0.00	0.02	1.04	0.01	-	-	1.08
		20	1.03	0.00	0.02	0.03	0.01	-	-	1.09
		21	1.04	0.00	0.02	0.02	0.01	-	-	1.10
		22	1.05	0.00	0.02	0.01	0.01	-	-	1.10
		23	1.06	0.00	0.02	0.01	0.01	-	-	1.11
		24	1.04	0.00	0.02	0.01	0.01	-	-	1.09
		25	0.37	0.17	0.03	0.28	0.21	-	-	1.05
		26	0.38	0.16	0.03	0.27	0.20	-	-	1.04
		27	0.40	0.16	0.03	0.27	0.21	-	-	1.07
		28	0.39	0.16	0.03	0.29	0.20	-	-	1.06
		29	0.40	0.15	0.03	0.27	0.21	-	-	1.06
		30	0.39	0.16	0.03	0.27	0.19	-	-	1.04
		31	0.38	0.16	0.04	0.26	0.17	-	-	1.01
		32	0.34	0.23	0.04	0.25	0.14	-	-	1.00
		33	0.33	0.26	0.04	0.24	0.11	-	-	0.98
		34	0.02	0.99	0.04	0.02	0.01	-	-	1.08
		35	0.01	0.99	0.04	0.02	0.01	-	-	1.07
		36	0.01	1.00	0.04	0.02	0.01	-	-	1.08
		37	0.01	1.01	0.04	0.02	0.01	-	-	1.08
		38	0.00	1.00	0.04	0.02	0.01	-	-	1.07
		39	0.01	0.89	0.04	0.04	0.01	-	-	0.99
		40	0.02	0.88	0.04	0.04	0.01	-	-	0.99
		41	0.07	0.78	0.04	0.07	0.01	-	-	0.98
		42	0.21	0.44	0.04	0.18	0.01	-	-	0.89
		43	0.27	0.31	0.04	0.22	0.01	-	-	0.86
		44	0.33	0.16	0.04	0.25	0.01	-	-	0.79
		45	0.36	0.09	0.05	0.32	0.01	-	-	0.83
		46	0.36	0.09	0.05	0.31	0.01	-	-	0.81
		47	-0.03	0.02	0.05	0.03	0.01	-	-	0.08
		48	-0.03	0.02	0.05	0.03	0.01	-	-	0.08

FLOW AND SEAL TEST PARAMETERS FOR TEST 204 ON 4/12/91

Parameter	LOCATION Seal 1	Seal 2	Seal 3	Seal 4	Forward	Inner	Aft
Ω, Rpm	1501	1501	1501	1501	1501	1501	1501
P, psia	54.54	53.83	52.70	52.17	53.03	53.41	53.37
T, °R	508	510	512	512	512	512	515
Rho, lb/(ft^3)	0.290	0.285	0.278	0.275	0.280	0.282	0.280
Emdot, lb/sec	-0.180	-0.109	0.274	0.306	0.201	0.094	0.103
μ, lb/(ft sec)	1.17E-05	1.17E-05	1.18E-05	1.18E-05	1.18E-05	1.18E-05	1.18E-05
Ro, in	9.12	9.12	9.12	9.12	9.12	9.12	9.12
Vo, ft/sec	119.434	119.434	119.434	119.434	119.434	119.434	119.434
Vϕ, ft/sec	204.518	0	203.452	0	-	-	-
Vz, ft/sec	67.440	72.223	73.005	89.147	-	-	-
Qo, psi	0.446	0.446	0.446	0.446	0.446	0.446	0.446
δp/q	0	-1.601	-4.139	-5.320	-3.395	-2.548	-2.638
Vϕ/Vo	1.712	0	1.703	0	-	-	-
Vz/Vo	0.565	0.605	0.611	0.746	-	-	-
Reto	2.25E+06	2.25E+06	2.25E+06	2.25E+06	2.25E+06	2.25E+06	2.25E+06
Rer	-3217	-1949	4880	5443	3576	1672	1817
Rer/(Ret^0.8)	-0.027	-0.016	0.040	0.045	0.030	0.014	0.015
Mϕ	0.185	0	0.183	0	-	-	-
Coolant Gas	-	-	-	-	Air	Air	Air

GAS SOURCE CONCENTRATION

TEST	-	PORT	ϕ12	ϕ13	ϕ14	ϕ01	ϕ03	ϕ05	ϕ07	TOTAL
204	A	1	0.00	-	0.00	0.00	0.00	0.00	-	0.01
		2	0.00	-	0.00	0.00	0.00	0.00	-	0.01
		3	0.00	-	0.00	0.00	0.02	-0.00	-	0.03
		4	0.01	-	0.01	0.01	0.04	0.00	-	0.06
		5	0.01	-	0.00	0.01	0.04	0.00	-	0.06
		6	0.02	-	0.00	0.01	0.05	0.00	-	0.08
		7	0.03	-	0.00	0.02	0.06	0.00	-	0.11
		8	0.13	-	0.00	0.10	0.11	0.00	-	0.35
		9	0.29	-	0.00	0.23	0.17	0.00	-	0.69
		10	0.37	-	0.00	0.28	0.79	0.00	-	1.45
		11	-	-	-	-	-	-	-	-
		12	0.59	-	0.00	0.40	0.01	0.00	-	1.00
		13	0.60	-	0.00	0.39	-0.00	0.00	-	1.00
		14	0.50	-	0.00	0.48	-0.01	0.00	-	0.98
		15	0.52	-	0.00	0.47	-0.01	0.00	-	0.98
		16	0.61	-	0.00	0.38	-0.02	0.00	-	0.98
		17	0.66	-	0.00	0.33	-0.03	0.00	-	0.97
		18	0.56	-	0.00	0.45	-0.04	0.00	-	0.99
		19	-	-	-	-	-	-	-	-
		20	0.52	-	0.00	0.46	-0.05	0.00	-	0.95
		21	0.79	-	0.00	0.22	-0.04	0.00	-	0.98
		22	0.91	-	0.01	0.11	-0.04	0.00	-	0.98
		23	0.11	-	0.00	0.89	-0.05	0.00	-	0.97
		24	1.00	-	0.01	0.02	-0.05	0.00	-	0.99
		25	1.02	-	0.00	0.01	-0.05	0.00	-	0.99
		26	1.00	-	0.00	0.01	-0.06	0.01	-	0.96
		27	1.02	-	0.00	0.01	-0.06	0.01	-	0.99
		28	1.02	-	0.01	0.01	-0.06	0.01	-	0.98
		29	1.02	-	0.01	0.00	-0.06	0.01	-	0.98
		30	1.02	-	0.01	0.00	-0.06	0.01	-	0.98
		31	1.02	-	0.01	0.00	-0.06	0.01	-	0.98
		32	1.02	-	0.01	0.00	-0.06	0.01	-	0.99
		33	1.02	-	0.01	-0.00	-0.06	0.01	-	0.98
		34	0.03	-	0.00	0.00	-0.06	0.01	-	-0.01
		35	0.02	-	0.01	0.00	-0.06	0.01	-	-0.02
		36	0.02	-	0.01	0.00	-0.06	0.01	-	-0.02
		37	0.02	-	0.01	0.00	-0.06	0.01	-	-0.02
		38	0.02	-	0.01	0.00	-0.05	0.01	-	-0.02
		39	0.02	-	0.01	0.00	-0.05	0.01	-	-0.02
	B	1	0.01	-	0.99	0.01	0.01	0.01	-	1.03
		2	0.01	-	0.99	0.01	0.02	0.01	-	1.03
		3	0.01	-	0.98	0.01	0.02	0.01	-	1.03
		4	0.01	-	0.98	0.01	0.02	0.01	-	1.03

GAS SOURCE CONCENTRATION (Cont.)

TEST	-	PORT	ϕ12	ϕ13	ϕ14	ϕ01	ϕ03	ϕ05	ϕ07	TOTAL
204	B	5	0.01	-	0.98	0.01	0.02	0.01	-	1.04
		6	0.01	-	0.98	0.01	0.02	0.01	-	1.04
		7	0.02	-	0.99	0.01	0.02	0.01	-	1.05
		8	0.02	-	0.99	0.01	0.02	0.01	-	1.04
		9	0.02	-	0.98	0.02	0.02	0.01	-	1.04
		10	0.36	-	0.04	0.27	0.30	0.01	-	0.97
		11	0.36	-	0.03	0.27	0.29	0.01	-	0.97
		12	0.37	-	0.02	0.28	0.30	0.01	-	0.97
		13	0.37	-	0.02	0.28	0.29	0.01	-	0.96
		14	0.37	-	0.02	0.28	0.30	0.01	-	0.98
		15	0.37	-	0.02	0.28	0.29	0.01	-	0.97
		16	0.37	-	0.02	0.28	0.28	0.01	-	0.96
		17	0.37	-	0.02	0.29	0.28	0.01	-	0.96
		18	0.37	-	0.02	0.28	0.27	0.01	-	0.95
		19	0.37	-	0.02	0.29	0.27	0.01	-	0.95
		20	0.38	-	0.02	0.29	0.27	0.00	-	0.95
		21	0.38	-	0.02	0.29	0.26	0.00	-	0.95
		22	0.32	-	0.02	0.24	0.23	0.00	-	0.81
		23	0.37	-	0.02	0.29	0.26	0.00	-	0.94
		24	0.36	-	0.02	0.28	0.25	0.00	-	0.92
		25	0.35	-	0.02	0.27	0.23	0.00	-	0.87
		26	0.32	-	0.02	0.24	0.22	0.00	-	0.80
		27	0.29	-	0.02	0.22	0.20	0.00	-	0.74
		28	0.26	-	0.02	0.20	0.18	0.00	-	0.66
		29	0.26	-	0.02	0.20	0.18	0.00	-	0.65
		30	0.10	-	0.02	0.08	0.01	0.00	-	0.21
	C	1	0.00	-	0.00	1.00	0.01	0.00	-	1.01
		2	0.00	-	0.00	0.01	0.99	0.00	-	1.00
		3	0.00	-	0.00	0.00	0.01	1.04	-	1.05
		4	0.00	-	0.00	0.00	0.00	0.00	-	0.02
		5	1.01	-	0.00	0.00	0.00	0.00	-	1.02
		6	0.01	-	0.00	0.00	0.00	0.00	-	0.01
		7	0.01	-	0.98	0.00	0.00	0.00	-	1.00
		8	0.01	-	0.97	0.01	0.01	0.00	-	1.00
		9	0.01	-	0.96	0.01	0.01	0.00	-	0.99
		10	0.01	-	0.96	0.01	0.02	0.00	-	1.00
		11	0.06	-	0.81	0.05	0.07	0.00	-	1.00
		12	0.07	-	0.10	0.05	0.06	0.00	-	0.29
		13	0.03	-	0.01	0.02	0.01	0.96	-	1.02
		14	0.01	-	0.00	0.00	0.95	0.00	-	0.97
		15	0.01	-	0.00	0.98	-0.02	0.00	-	0.98
		16	0.01	-	0.00	0.99	-0.02	0.00	-	0.98
		17	0.01	-	0.00	0.99	-0.03	0.00	-	0.98
		18	0.01	-	0.00	0.99	-0.04	0.00	-	0.97
		19	0.01	-	0.00	0.99	-0.04	0.01	-	0.97
		20	1.01	-	0.00	0.02	-0.04	0.00	-	0.99
		21	1.01	-	0.01	0.01	-0.04	0.00	-	0.99
		22	1.02	-	0.01	0.01	-0.05	0.00	-	0.99
		23	1.02	-	0.01	0.00	-0.05	0.00	-	0.99
		24	1.02	-	0.01	0.00	-0.05	0.00	-	0.98
		25	0.37	-	0.00	0.28	0.25	0.01	-	0.91
		26	0.38	-	0.00	0.28	0.24	0.01	-	0.91
		27	0.38	-	0.00	0.28	0.24	0.01	-	0.91
		28	0.38	-	0.01	0.29	0.24	0.01	-	0.92
		29	0.38	-	0.01	0.27	0.25	0.01	-	0.92
		30	0.38	-	0.01	0.27	0.25	0.01	-	0.91
		31	0.38	-	0.02	0.28	0.25	-0.00	-	0.93
		32	0.34	-	0.02	0.26	0.23	-0.00	-	0.85
		33	0.33	-	0.02	0.24	0.23	-0.00	-	0.81
		34	0.03	-	0.02	0.02	-0.04	-0.00	-	0.02
		35	0.02	-	0.02	0.02	-0.05	-0.00	-	0.01
		36	0.02	-	0.02	0.02	-0.04	-0.00	-	0.01
		37	0.03	-	0.02	0.02	-0.04	-0.00	-	0.01
		38	0.02	-	0.02	0.02	-0.04	-0.00	-	0.01
		39	0.04	-	0.02	0.03	0.04	-0.01	-	0.13
		40	0.05	-	0.02	0.04	0.06	-0.01	-	0.16
		41	0.09	-	0.02	0.07	0.14	-0.01	-	0.31
		42	0.24	-	0.02	0.17	0.22	-0.01	-	0.64
		43	0.30	-	0.02	0.22	0.24	-0.01	-	0.77
		44	0.38	-	0.02	0.27	0.28	-0.01	-	0.94
		45	0.41	-	0.02	0.33	0.26	-0.01	-	1.00
		46	0.40	-	0.02	0.32	0.25	-0.01	-	0.99
		47	0.03	-	0.02	0.02	0.88	-0.01	-	0.94
		48	0.02	-	0.02	0.02	0.89	-0.01	-	0.94

FLOW AND SEAL TEST PARAMETERS FOR TEST 205 ON 4/9/91

Parameter	LOCATION Seal 1	Seal 2	Seal 3	Seal 4	Forward	Inner	Aft
Ω, Rpm	1504	1504	1504	1504	1504	1504	1504
P, psia	57.79	57.03	55.85	55.38	56.21	56.69	56.60
T, °R	526	526	524	524	528	528	531
Rho, lb/(ft^3)	0.296	0.293	0.288	0.286	0.287	0.290	0.288
Emdot, lb/sec	-0.186	-0.113	0.302	0.302	0.208	0.105	0.095
μ, lb/(ft sec)	1.20E-05	1.20E-05	1.20E-05	1.20E-05	1.21E-05	1.21E-05	1.21E-05
Ro, in	9.12	9.12	9.12	9.12	9.12	9.12	9.12
Vo, ft/sec	119.667	119.667	119.667	119.667	119.667	119.667	119.667
Vϕ, ft/sec	202.023	0	184.178	0	-	-	-
Vz, ft/sec	67.379	67.833	66.844	82.895	-	-	-
Qo, psi	0.458	0.458	0.458	0.458	0.458	0.458	0.458
δp/q	0	-1.655	-4.232	-5.267	-3.440	-2.404	-2.600
Vϕ/Vo	1.688	0	1.539	0	-	-	-
Vz/Vo	0.563	0.567	0.559	0.693	-	-	-
Reto	2.24E+06	2.24E+06	2.24E+06	2.24E+06	2.24E+06	2.24E+06	2.24E+06
Rer	-3242	-1966	5282	5283	3605	1820	1647
Rer/(Ret^0.8)	-0.027	-0.016	0.044	0.044	0.030	0.015	0.014
Mϕ	0.180	0	0.164	0	-	-	-
Coolant Gas	-	-	-	-	Air	Air	Air

GAS SOURCE CONCENTRATION

TEST	-	PORT	ϕ12	ϕ13	ϕ14	ϕ01	ϕ03	ϕ05	ϕ07	TOTAL
205	A	1	0.00	0.99	0.00	-	0.00	-	-	0.99
		2	0.00	0.99	0.00	-	0.00	-	-	0.99
		3	0.00	1.00	0.00	-	0.00	-	-	1.00
		4	0.01	0.99	0.00	-	0.00	-	-	1.00
		5	0.01	0.99	0.00	-	0.00	-	-	1.00
		6	0.01	0.97	0.01	-	0.00	-	-	0.99
		7	0.02	0.96	0.01	-	0.00	-	-	0.98
		8	0.11	0.74	0.01	-	0.00	-	-	0.86
		9	0.27	0.39	0.01	-	0.00	-	-	0.67
		10	0.29	0.01	0.01	-	0.00	-	-	0.30
		11	-	-	-	-	-	-	-	-
		12	0.58	0.01	0.01	-	0.00	-	-	0.61
		13	0.59	0.01	0.01	-	0.00	-	-	0.61
		14	0.48	0.01	0.01	-	0.00	-	-	0.50
		15	0.53	0.01	0.01	-	0.00	-	-	0.56
		16	0.63	0.01	0.01	-	0.00	-	-	0.65
		17	0.66	0.01	0.01	-	0.00	-	-	0.68
		18	0.55	0.01	0.02	-	0.00	-	-	0.58
		19	-	-	-	-	-	-	-	-
		20	0.50	0.01	0.02	-	0.00	-	-	0.53
		21	0.78	0.01	0.02	-	0.00	-	-	0.81
		22	0.92	0.01	0.02	-	0.00	-	-	0.94
		23	0.11	0.01	0.02	-	0.00	-	-	0.14
		24	1.02	0.01	0.02	-	0.00	-	-	1.05
		25	1.02	0.01	0.02	-	0.00	-	-	1.05
		26	1.01	0.01	0.02	-	0.00	-	-	1.04
		27	1.01	0.00	0.02	-	0.00	-	-	1.03
		28	1.01	0.01	0.02	-	0.00	-	-	1.04
		29	1.00	0.01	0.02	-	0.00	-	-	1.03
		30	0.99	0.01	0.02	-	0.00	-	-	1.02
		31	1.01	0.01	0.02	-	0.00	-	-	1.04
		32	1.01	0.00	0.02	-	0.00	-	-	1.04
		33	1.01	0.00	0.02	-	0.00	-	-	1.03
		34	-0.04	0.99	0.02	-	0.00	-	-	0.97
		35	-0.04	0.99	0.02	-	0.00	-	-	0.97
		36	-0.04	0.99	0.02	-	0.00	-	-	0.97
		37	-0.04	0.99	0.03	-	0.00	-	-	0.97
		38	-0.04	0.99	0.03	-	0.00	-	-	0.97
		39	-0.05	0.98	0.03	-	0.00	-	-	0.96
	B	1	-0.13	0.00	1.03	-	0.00	-	-	0.90
		2	-0.13	0.00	1.04	-	0.00	-	-	0.92
		3	-0.12	0.01	1.02	-	0.00	-	-	0.91
		4	-0.12	0.01	1.02	-	0.00	-	-	0.91

GAS SOURCE CONCENTRATION (Cont.)

TEST	-	PORT	Ø12	Ø13	Ø14	Ø01	Ø03	Ø05	Ø07	TOTAL
205	B	5	-0.12	0.01	1.02	-	0.00	-	-	0.91
		6	-0.12	0.01	1.03	-	0.00	-	-	0.91
		7	-0.12	0.01	1.04	-	0.00	-	-	0.92
		8	-0.12	0.01	1.03	-	0.00	-	-	0.92
		9	-0.12	0.01	1.03	-	0.00	-	-	0.92
		10	0.27	0.18	-0.08	-	0.00	-	-	0.36
		11	0.28	0.18	-0.10	-	0.00	-	-	0.36
		12	0.28	0.19	-0.11	-	0.00	-	-	0.36
		13	0.29	0.18	-0.11	-	0.00	-	-	0.36
		14	0.29	0.18	-0.11	-	0.00	-	-	0.36
		15	0.29	0.18	-0.11	-	0.00	-	-	0.36
		16	0.29	0.19	-0.11	-	0.00	-	-	0.37
		17	0.30	0.19	-0.11	-	0.00	-	-	0.37
		18	0.30	0.18	-0.11	-	0.00	-	-	0.37
		19	0.30	0.18	-0.11	-	0.00	-	-	0.37
		20	0.30	0.18	-0.11	-	0.00	-	-	0.37
		21	0.30	0.18	-0.11	-	0.00	-	-	0.37
		22	0.23	0.31	-0.11	-	0.00	-	-	0.42
		23	0.30	0.17	-0.11	-	0.00	-	-	0.37
		24	0.29	0.20	-0.11	-	0.00	-	-	0.38
		25	0.25	0.24	-0.10	-	0.00	-	-	0.39
		26	0.21	0.30	-0.10	-	0.00	-	-	0.41
		27	0.17	0.36	-0.10	-	0.00	-	-	0.43
		28	0.13	0.42	-0.10	-	0.00	-	-	0.45
		29	0.13	0.44	-0.10	-	0.00	-	-	0.47
		30	-0.07	0.81	-0.10	-	0.00	-	-	0.64
	C	1	0.00	0.00	0.00	-	0.00	-	-	0.01
		2	0.00	0.00	0.00	-	0.00	-	-	0.01
		3	0.00	0.00	0.00	-	0.00	-	-	0.01
		4	0.00	0.00	0.01	-	0.00	-	-	0.01
		5	1.02	0.00	0.01	-	0.00	-	-	1.02
		6	0.00	1.00	0.01	-	0.00	-	-	1.00
		7	0.00	0.01	1.02	-	0.00	-	-	1.03
		8	0.01	0.01	1.00	-	0.00	-	-	1.02
		9	0.01	0.01	1.00	-	0.00	-	-	1.02
		10	0.01	0.01	1.00	-	0.00	-	-	1.01
		11	0.06	0.04	0.82	-	0.00	-	-	0.92
		12	0.06	0.04	0.10	-	0.00	-	-	0.20
		13	0.02	0.01	0.01	-	0.00	-	-	0.05
		14	0.00	0.00	0.01	-	0.00	-	-	0.02
		15	0.00	0.00	0.01	-	0.00	-	-	0.02
		16	0.00	0.00	0.01	-	0.00	-	-	0.02
		17	0.00	0.00	0.02	-	0.00	-	-	0.02
		18	0.00	0.00	0.02	-	0.00	-	-	0.02
		19	0.00	0.00	0.02	-	0.00	-	-	0.02
		20	1.01	0.00	0.02	-	0.00	-	-	1.03
		21	1.02	0.01	0.02	-	0.00	-	-	1.04
		22	1.03	0.00	0.02	-	0.00	-	-	1.05
		23	1.03	0.01	0.02	-	0.00	-	-	1.05
		24	1.03	0.00	0.02	-	0.00	-	-	1.05
		25	0.33	0.17	0.02	-	0.00	-	-	0.51
		26	0.33	0.17	0.02	-	0.00	-	-	0.52
		27	0.33	0.17	0.02	-	0.00	-	-	0.51
		28	0.32	0.16	0.02	-	0.00	-	-	0.51
		29	0.33	0.15	0.02	-	0.00	-	-	0.50
		30	0.32	0.16	0.02	-	0.00	-	-	0.50
		31	0.27	0.15	-0.10	-	0.00	-	-	0.32
		32	0.22	0.23	-0.10	-	0.00	-	-	0.34
		33	0.20	0.25	-0.10	-	0.00	-	-	0.35
		34	-0.17	0.96	-0.10	-	0.00	-	-	0.69
		35	-0.17	0.97	-0.10	-	0.00	-	-	0.70
		36	-0.18	0.96	-0.10	-	0.00	-	-	0.69
		37	-0.18	0.97	-0.10	-	0.00	-	-	0.69
		38	-0.18	0.96	-0.10	-	0.00	-	-	0.69
		39	-0.16	0.92	-0.10	-	0.00	-	-	0.66
		40	-0.15	0.90	-0.10	-	0.00	-	-	0.66
		41	-0.10	0.81	-0.10	-	0.00	-	-	0.62
		42	0.09	0.49	-0.10	-	0.00	-	-	0.48
		43	0.17	0.34	-0.09	-	0.00	-	-	0.41
		44	0.28	0.14	-0.09	-	0.00	-	-	0.33
		45	0.30	0.07	-0.09	-	0.00	-	-	0.27
		46	0.26	0.07	-0.09	-	0.00	-	-	0.24
		47	-0.19	0.00	-0.09	-	0.00	-	-	-0.28
		48	-0.19	0.00	-0.09	-	0.00	-	-	-0.28

FLOW AND SEAL TEST PARAMETERS FOR TEST 206 ON 4/11/91

Parameter	Seal 1	Seal 2	Seal 3	Seal 4	Forward	Inner	Aft
	LOCATION						
Ω, Rpm	1502	1502	1502	1502	1502	1502	1502
P, psia	54.12	53.49	52.30	51.85	52.69	53.11	53.00
T, °R	515	516	517	517	519	518	522
Rho, lb/(ft^3)	0.284	0.280	0.273	0.271	0.274	0.277	0.274
Emdot, lb/sec	-0.182	-0.110	0.317	0.303	0.214	0.100	0.103
μ, lb/(ft sec)	1.18E-05	1.18E-05	1.19E-05	1.19E-05	1.19E-05	1.19E-05	1.20E-05
Ro, in	9.12	9.12	9.12	9.12	9.12	9.12	9.12
Vo, ft/sec	119.552	119.552	119.552	119.552	119.552	119.552	119.552
Vφ, ft/sec	205.470	0	201.619	0	-	-	-
Vz, ft/sec	68.528	73.216	73.173	91.378	-	-	-
Qo, psi	0.438	0.438	0.438	0.438	0.438	0.438	0.438
δp/q	0	-1.438	-4.167	-5.202	-3.266	-2.325	-2.577
Vφ/Vo	1.719	0	1.686	0	-	-	-
Vz/Vo	0.573	0.612	0.612	0.764	-	-	-
Reto	2.18E+06	2.18E+06	2.18E+06	2.18E+06	2.18E+06	2.18E+06	2.18E+06
Rer	-3218	-1947	5598	5348	3768	1771	1804
Rer/(Ret^0.8)	-0.027	-0.017	0.048	0.045	0.032	0.015	0.015
Mφ	0.185	0	0.181	0	-	-	-
Coolant Gas	-	-	-	-	Air	Air	Air

GAS SOURCE CONCENTRATION

TEST	-	PORT	φ12	φ13	φ14	φ01	φ03	φ05	φ07	TOTAL
206	A	1	0.00	1.02	0.00	0.00	-	-	-	1.03
		2	0.00	1.01	0.00	0.00	-	-	-	1.01
		3	0.01	1.00	0.00	0.00	-	-	-	1.01
		4	0.01	1.01	0.00	0.00	-	-	-	1.01
		5	0.01	1.01	0.00	0.00	-	-	-	1.02
		6	0.02	0.97	0.00	0.00	-	-	-	0.99
		7	0.03	0.95	0.00	0.00	-	-	-	0.98
		8	0.14	0.69	0.00	0.00	-	-	-	0.84
		9	0.31	0.39	0.00	0.00	-	-	-	0.69
		10	0.35	0.01	0.00	0.00	-	-	-	0.36
		11	-	-	-	-	-	-	-	-
		12	0.60	0.02	0.00	0.00	-	-	-	0.62
		13	0.61	0.02	0.00	0.00	-	-	-	0.63
		14	0.51	0.02	0.00	0.00	-	-	-	0.53
		15	0.54	0.02	0.00	0.00	-	-	-	0.55
		16	0.64	0.02	0.00	0.00	-	-	-	0.66
		17	0.68	0.02	0.00	0.00	-	-	-	0.70
		18	0.56	0.02	0.00	0.00	-	-	-	0.58
		19	-	-	-	-	-	-	-	-
		20	0.53	0.02	0.00	0.00	-	-	-	0.55
		21	0.80	0.02	0.00	0.00	-	-	-	0.82
		22	0.91	0.02	0.00	0.00	-	-	-	0.93
		23	0.12	0.02	0.00	0.00	-	-	-	0.14
		24	1.00	0.02	0.00	0.00	-	-	-	1.02
		25	1.01	0.02	0.00	0.00	-	-	-	1.03
		26	1.00	0.03	0.00	0.00	-	-	-	1.03
		27	1.01	0.02	0.00	0.00	-	-	-	1.04
		28	1.02	0.02	0.00	0.00	-	-	-	1.04
		29	1.01	0.03	0.00	0.00	-	-	-	1.03
		30	1.01	0.03	0.00	0.00	-	-	-	1.04
		31	1.01	0.02	0.00	0.00	-	-	-	1.03
		32	1.01	0.02	0.00	0.00	-	-	-	1.03
		33	1.02	0.02	0.00	0.00	-	-	-	1.04
		34	0.01	1.01	0.00	0.00	-	-	-	1.02
		35	0.01	1.01	0.00	0.00	-	-	-	1.02
		36	0.01	1.01	0.00	0.00	-	-	-	1.02
		37	0.01	1.02	0.00	0.00	-	-	-	1.03
		38	0.01	1.02	0.00	0.00	-	-	-	1.03
		39	0.01	1.02	0.00	0.00	-	-	-	1.03
	B	1	0.02	0.01	0.99	0.00	-	-	-	1.02
		2	0.02	0.01	0.99	0.00	-	-	-	1.02
		3	0.02	0.01	1.00	0.00	-	-	-	1.03
		4	0.02	0.01	0.99	0.00	-	-	-	1.02

GAS SOURCE CONCENTRATION (Cont.)

TEST	-	PORT	ϕ12	ϕ13	ϕ14	ϕ01	ϕ03	ϕ05	ϕ07	TOTAL
206	B	5	0.02	0.01	1.00	0.00	-	-	-	1.03
		6	0.02	0.01	0.99	0.00	-	-	-	1.03
		7	0.02	0.01	0.99	0.00	-	-	-	1.03
		8	0.02	0.02	1.01	0.00	-	-	-	1.04
		9	0.02	0.02	1.01	0.00	-	-	-	1.05
		10	0.37	0.19	0.04	0.00	-	-	-	0.60
		11	0.37	0.20	0.04	0.00	-	-	-	0.60
		12	0.38	0.20	0.02	0.00	-	-	-	0.60
		13	0.38	0.20	0.01	0.00	-	-	-	0.60
		14	0.38	0.20	0.02	0.00	-	-	-	0.60
		15	0.39	0.21	0.02	0.00	-	-	-	0.61
		16	0.38	0.21	0.02	0.00	-	-	-	0.60
		17	0.39	0.21	0.02	0.00	-	-	-	0.61
		18	0.39	0.21	0.02	0.00	-	-	-	0.61
		19	0.39	0.20	0.02	0.00	-	-	-	0.60
		20	0.39	0.20	0.02	0.00	-	-	-	0.61
		21	0.39	0.21	0.02	0.00	-	-	-	0.61
		22	0.33	0.34	0.02	0.00	-	-	-	0.68
		23	0.40	0.20	0.02	0.00	-	-	-	0.61
		24	0.39	0.22	0.02	0.00	-	-	-	0.62
		25	0.37	0.26	0.02	0.00	-	-	-	0.64
		26	0.33	0.33	0.02	0.00	-	-	-	0.68
		27	0.31	0.40	0.02	0.00	-	-	-	0.72
		28	0.28	0.46	0.02	0.00	-	-	-	0.76
		29	0.27	0.48	0.02	0.00	-	-	-	0.76
		30	0.11	0.85	0.02	0.00	-	-	-	0.97
	C	1	0.01	0.01	0.00	0.00	-	-	-	0.01
		2	0.00	0.01	0.00	0.00	-	-	-	0.01
		3	0.00	0.01	0.00	0.00	-	-	-	0.01
		4	0.00	0.01	0.00	0.00	-	-	-	0.01
		5	1.01	0.01	0.00	0.00	-	-	-	1.02
		6	0.01	0.99	0.00	0.00	-	-	-	1.00
		7	0.01	0.01	0.99	0.00	-	-	-	1.01
		8	0.01	0.01	0.98	0.00	-	-	-	1.01
		9	0.01	0.01	0.99	0.00	-	-	-	1.02
		10	0.01	0.01	0.99	0.00	-	-	-	1.01
		11	0.06	0.04	0.84	0.00	-	-	-	0.94
		12	0.07	0.04	0.10	0.00	-	-	-	0.22
		13	0.03	0.02	0.00	0.00	-	-	-	0.06
		14	0.01	0.01	0.00	0.00	-	-	-	0.02
		15	0.01	0.01	0.00	0.00	-	-	-	0.02
		16	0.01	0.01	0.00	0.00	-	-	-	0.02
		17	0.01	0.01	0.00	0.00	-	-	-	0.02
		18	0.01	0.01	0.00	0.00	-	-	-	0.02
		19	0.01	0.01	0.00	0.00	-	-	-	0.03
		20	1.00	0.02	0.00	0.00	-	-	-	1.02
		21	1.00	0.02	0.00	0.00	-	-	-	1.02
		22	1.01	0.02	0.00	0.00	-	-	-	1.03
		23	1.01	0.02	0.00	0.00	-	-	-	1.03
		24	1.01	0.02	0.00	0.00	-	-	-	1.03
		25	0.37	0.19	0.00	0.00	-	-	-	0.56
		26	0.39	0.19	0.00	0.00	-	-	-	0.58
		27	0.39	0.19	0.00	0.00	-	-	-	0.58
		28	0.39	0.18	0.00	0.00	-	-	-	0.57
		29	0.39	0.17	0.00	0.00	-	-	-	0.56
		30	0.39	0.19	0.00	0.00	-	-	-	0.57
		31	0.40	0.19	0.02	0.00	-	-	-	0.60
		32	0.36	0.26	0.02	0.00	-	-	-	0.63
		33	0.35	0.28	0.02	0.00	-	-	-	0.64
		34	0.03	0.99	0.02	0.00	-	-	-	1.04
		35	0.03	1.00	0.02	0.00	-	-	-	1.05
		36	0.03	1.01	0.02	0.00	-	-	-	1.05
		37	0.03	0.96	0.02	0.00	-	-	-	1.01
		38	0.03	1.00	0.02	0.00	-	-	-	1.05
		39	0.05	0.98	0.02	0.00	-	-	-	1.04
		40	0.05	0.97	0.02	0.00	-	-	-	1.04
		41	0.09	0.87	0.02	0.00	-	-	-	0.98
		42	0.24	0.54	0.02	0.00	-	-	-	0.79
		43	0.31	0.39	0.02	0.00	-	-	-	0.71
		44	0.40	0.18	0.02	0.00	-	-	-	0.60
		45	0.43	0.11	0.02	0.00	-	-	-	0.56
		46	0.43	0.11	0.02	0.00	-	-	-	0.56
		47	0.03	0.04	0.02	0.00	-	-	-	0.09
		48	0.03	0.04	0.02	0.00	-	-	-	0.09

FLOW AND SEAL TEST PARAMETERS FOR TEST 210   ON 4/22/91

Parameter	LOCATION						
	Seal 1	Seal 2	Seal 3	Seal 4	Forward	Inner	Aft
Ω, Rpm	1497	1497	1497	1497	1497	1497	1497
P, psia	60.90	60.06	58.92	58.28	59.51	59.64	59.54
T, °R	511	511	512	512	515	513	516
Rho, lb/(ft^3)	0.322	0.317	0.311	0.307	0.312	0.314	0.311
Emdot, lb/sec	-0.313	-0.217	0.340	0.431	0.177	0.086	0.101
μ, lb/(ft sec)	1.18E-05	1.18E-05	1.18E-05	1.18E-05	1.18E-05	1.18E-05	1.19E-05
Ro, in	9.12	9.12	9.12	9.12	9.12	9.12	9.12
Vo, ft/sec	119.147	119.147	119.147	119.147	119.147	119.147	119.147
Vϕ, ft/sec	192.810	0	191.257	0	-	-	-
Vz, ft/sec	64.306	68.024	69.413	86.455	-	-	-
Qo, psi	0.493	0.493	0.493	0.493	0.493	0.493	0.493
δp/q	0	-1.695	-4.009	-5.307	-2.827	-2.563	-2.760
Vϕ/Vo	1.618	0	1.605	0	-	-	-
Vz/Vo	0.540	0.571	0.583	0.726	-	-	-
Reto	2.48E+06	2.48E+06	2.48E+06	2.48E+06	2.48E+06	2.48E+06	2.48E+06
Rer	-5570	-3868	6040	7660	3126	1531	1788
Rer/(Ret^0.8)	-0.043	-0.030	0.046	0.059	0.024	0.012	0.014
Mϕ	0.174	0	0.172	0	-	-	-
Coolant Gas	-	-	-	-	Air	Air	Air

GAS SOURCE CONCENTRATION

TEST	-	PORT	ϕ13
210	A	1	1.02
		2	1.01
		3	1.01
		4	0.99
		5	0.98
		6	0.97
		7	0.80
		8	0.38
		9	0.20
		10	0.00

TEST	-	PORT	ϕ13
210	C	36	0.97
		37	0.98
		39	0.90
		40	0.88
		41	0.77
		42	0.32
		43	0.27
		44	0.08
		45	0.04
		47	0.00

FLOW AND SEAL TEST PARAMETERS FOR TEST 211 ON 4/22/91

Parameter	Seal 1	Seal 2	Seal 3	Seal 4	Forward	Inner	Aft
	LOCATION						
Ω, Rpm	1503	1503	1503	1503	1503	1503	1503
P, psia	61.02	60.24	59.06	58.49	59.72	59.80	59.68
T, °R	515	515	514	514	519	516	519
Rho, lb/(ft^3)	0.320	0.316	0.310	0.307	0.310	0.313	0.310
Emdot, lb/sec	-0.292	-0.225	0.379	0.440	0.160	0.079	0.101
μ, lb/(ft sec)	1.18E-05	1.18E-05	1.18E-05	1.18E-05	1.19E-05	1.18E-05	1.19E-05
Ro, in	9.12	9.12	9.12	9.12	9.12	9.12	9.12
Vo, ft/sec	119.621	119.621	119.621	119.621	119.621	119.621	119.621
$V\phi$, ft/sec	192.436	0	192.123	0	-	-	-
Vz, ft/sec	64.181	69.567	69.727	86.870	-	-	-
Qo, psi	0.494	0.494	0.494	0.494	0.494	0.494	0.494
$\delta p/q$	0	-1.574	-3.962	-5.121	-2.615	-2.457	-2.711
$V\phi$/Vo	1.609	0	1.606	0	-	-	-
Vz/Vo	0.537	0.582	0.583	0.726	-	-	-
Reto	2.46E+06	2.46E+06	2.46E+06	2.46E+06	2.46E+06	2.46E+06	2.46E+06
Rer	-5176	-3986	6708	7791	2820	1400	1780
Rer/(Ret^0.8)	-0.040	-0.031	0.052	0.060	0.022	0.011	0.014
$M\phi$	0.173	0	0.173	0	-	-	-
Coolant Gas	-	-	-	-	Air	Air	Air

GAS SOURCE CONCENTRATION

TEST	-	PORT	ϕ13
211	A	1	1.00
		2	1.00
		3	0.97
		4	0.95
		5	0.95
		6	0.93
		7	0.74
		8	0.33
		9	0.22
		10	0.01

TEST	-	PORT	ϕ13
211	C	36	0.98
		37	0.88
		39	0.96
		40	0.99
		41	0.86
		42	0.84
		43	0.71
		44	0.28
		45	0.24
		47	0.04

FLOW AND SEAL TEST PARAMETERS FOR TEST 212 ON 4/22/91

Parameter	LOCATION						
	Seal 1	Seal 2	Seal 3	Seal 4	Forward	Inner	Aft
Ω, Rpm	1495	1495	1495	1495	1495	1495	1495
P, psia	61.02	60.13	58.99	58.42	59.66	59.75	59.67
T, °R	516	515	516	516	520	517	520
Rho, lb/(ft^3)	0.319	0.315	0.308	0.305	0.310	0.312	0.310
Emdot, lb/sec	-0.312	-0.227	0.335	0.421	0.145	0.071	0.101
μ, lb/(ft sec)	1.18E-05	1.18E-05	1.19E-05	1.19E-05	1.19E-05	1.19E-05	1.19E-05
Ro, in	9.12	9.12	9.12	9.12	9.12	9.12	9.12
Vo, ft/sec	118.945	118.945	118.945	118.945	118.945	118.945	118.945
Vφ, ft/sec	192.772	0	194.506	0	-	-	-
Vz, ft/sec	64.293	69.543	70.592	87.552	-	-	-
Qo, psi	0.487	0.487	0.487	0.487	0.487	0.487	0.487
δp/q	0	-1.825	-4.175	-5.345	-2.786	-2.615	-2.767
Vφ/Vo	1.621	0	1.635	0	-	-	-
Vz/Vo	0.541	0.585	0.593	0.736	-	-	-
Reto	2.44E+06	2.44E+06	2.44E+06	2.44E+06	2.44E+06	2.44E+06	2.44E+06
Rer	-5520	-4020	5922	7430	2541	1258	1773
Rer/(Ret^0.8)	-0.043	-0.031	0.046	0.058	0.020	0.010	0.014
Mφ	0.173	0	0.175	0	-	-	-
Coolant Gas	-	-	-	-	Air	Air	Air

GAS SOURCE CONCENTRATION

TEST	-	PORT	φ13
212	A	1	1.00
↓	↓	2	1.00
		3	0.98
		4	0.96
		5	0.95
		6	0.92
		7	0.69
		8	0.32
		9	0.17
		10	0.00

TEST	-	PORT	φ13
212	C	36	0.98
↓	↓	37	0.98
		39	0.97
		40	0.85
		41	0.81
		42	0.66
		43	0.25
		44	0.24
		45	0.08
		47	0.08

FLOW AND SEAL TEST PARAMETERS FOR TEST 213 ON 4/22/91

Parameter	LOCATION						
	Seal 1	Seal 2	Seal 3	Seal 4	Forward	Inner	Aft
Ω, Rpm	1492	1492	1492	1492	1492	1492	1492
P, psia	60.99	60.07	58.96	58.36	59.56	59.59	59.54
T, °R	516	516	517	517	520	516	520
Rho, lb/(ft^3)	0.319	0.314	0.308	0.305	0.309	0.312	0.309
Emdot, lb/sec	-0.329	-0.240	0.319	0.410	0.102	0.048	0.101
μ, lb/(ft sec)	1.19E-05	1.19E-05	1.19E-05	1.19E-05	1.19E-05	1.19E-05	1.19E-05
Ro, in	9.12	9.12	9.12	9.12	9.12	9.12	9.12
Vo, ft/sec	118.783	118.783	118.783	118.783	118.783	118.783	118.783
Vϕ, ft/sec	198.108	0	197.584	0	-	-	-
Vz, ft/sec	65.326	70.137	70.899	88.234	-	-	-
Qo, psi	0.485	0.485	0.485	0.485	0.485	0.485	0.485
δp/q	0	-1.896	-4.180	-5.415	-2.937	-2.874	-2.985
Vϕ/Vo	1.668	0	1.663	0	-	-	-
Vz/Vo	0.550	0.590	0.597	0.743	-	-	-
Reto	2.43E+06	2.43E+06	2.43E+06	2.43E+06	2.43E+06	2.43E+06	2.43E+06
Rer	-5809	-4232	5637	7234	1790	855	1768
Rer/(Ret^0.8)	-0.045	-0.033	0.044	0.056	0.014	0.007	0.014
Mϕ	0.178	0	0.177	0	-	-	-
Coolant Gas	-	-	-	-	Air	Air	Air

GAS SOURCE CONCENTRATION

TEST	-	PORT	ϕ13
213	A	1	1.02
↓	↓	2	1.03
		3	0.92
		4	0.87
		5	0.87
		6	0.84
		7	0.55
		8	0.20
		9	0.08
		10	0.00

TEST	-	PORT	ϕ13
213	C	36	1.02
↓	↓	37	1.02
		39	0.71
		40	0.65
		41	0.48
		42	0.16
		43	0.14
		44	0.06
		45	0.03
		47	0.00

FLOW AND SEAL TEST PARAMETERS FOR TEST 214   ON 4/22/91

Parameter	LOCATION Seal 1	Seal 2	Seal 3	Seal 4	Forward	Inner	Aft
Ω, Rpm	1493	1493	1493	1493	1493	1493	1493
P, psia	61.34	60.38	59.32	58.61	59.94	60.13	59.91
T, °R	516	516	513	513	519	516	520
Rho, lb/(ft^3)	0.321	0.316	0.312	0.308	0.312	0.315	0.311
Emdot, lb/sec	-0.338	-0.255	0.293	0.417	0.072	0.034	0.101
μ, lb/(ft sec)	1.18E-05	1.18E-05	1.18E-05	1.18E-05	1.19E-05	1.18E-05	1.19E-05
Ro, in	9.12	9.12	9.12	9.12	9.12	9.12	9.12
Vo, ft/sec	118.805	118.805	118.805	118.805	118.805	118.805	118.805
Vφ, ft/sec	195.604	0	194.230	0	-	-	-
Vz, ft/sec	65.238	69.927	70.492	87.317	-	-	-
Qo, psi	0.489	0.489	0.489	0.489	0.489	0.489	0.489
δp/q	0	-1.951	-4.124	-5.586	-2.860	-2.468	-2.909
Vφ/Vo	1.646	0	1.635	0	-	-	-
Vz/Vo	0.549	0.589	0.593	0.735	-	-	-
Reto	2.45E+06	2.45E+06	2.45E+06	2.45E+06	2.45E+06	2.45E+06	2.45E+06
Rer	-5974	-4515	5204	7402	1259	605	1774
Rer/(Ret^0.8)	-0.046	-0.035	0.040	0.057	0.010	0.005	0.014
Mφ	0.176	0	0.175	0	-	-	-
Coolant Gas	-	-	-	-	Air	Air	Air

GAS SOURCE CONCENTRATION

TEST	-	PORT	φ13
214	A	1	0.99
		2	1.00
		3	0.77
		4	0.69
		5	0.69
		6	0.67
		7	0.38
		8	0.10
		9	0.03
		10	0.00

TEST	-	PORT	φ13
214	C	36	-
		37	-
		39	-
		40	-
		41	-
		42	-
		43	-
		44	-
		45	-
		47	-

FLOW AND SEAL TEST PARAMETERS FOR TEST 220 ON 4/22/91

Parameter	LOCATION						
	Seal 1	Seal 2	Seal 3	Seal 4	Forward	Inner	Aft
Ω, Rpm	1495	1495	1495	1495	1495	1495	1495
P, psia	61.09	60.36	59.22	58.72	59.84	59.99	59.89
T, °R	512	512	513	513	516	513	516
Rho, lb/(ft^3)	0.322	0.318	0.312	0.309	0.313	0.315	0.313
Emdot, lb/sec	-0.290	-0.217	0.345	0.412	0.164	0.099	0.101
μ, lb/(ft sec)	1.18E-05	1.18E-05	1.18E-05	1.18E-05	1.19E-05	1.18E-05	1.19E-05
Ro, in	9.12	9.12	9.12	9.12	9.12	9.12	9.12
Vo, ft/sec	119.013	119.013	119.013	119.013	119.013	119.013	119.013
Vφ, ft/sec	189.175	0	189.375	0	-	-	-
Vz, ft/sec	63.094	67.834	68.730	85.860	-	-	-
Qo, psi	0.492	0.492	0.492	0.492	0.492	0.492	0.492
δp/q	0	-1.476	-3.810	-4.820	-2.538	-2.246	-2.445
Vφ/Vo	1.590	0	1.591	0	-	-	-
Vz/Vo	0.530	0.570	0.577	0.721	-	-	-
Reto	2.48E+06	2.48E+06	2.48E+06	2.48E+06	2.48E+06	2.48E+06	2.48E+06
Rer	-5153	-3856	6129	7314	2906	1751	1789
Rer/(Ret^0.8)	-0.040	-0.030	0.047	0.056	0.022	0.013	0.014
Mφ	0.171	0	0.171	0	-	-	-
Coolant Gas	-	-	-	-	Air	Air	Air

GAS SOURCE CONCENTRATION

TEST	-	PORT	φ12
220	A	23	0.03
↓	↓	24	0.99
		25	1.03
		26	1.01
		27	1.02
		28	1.02
		29	1.02
		30	1.02
		31	1.01

TEST	-	PORT	φ12
220	C	5	1.00
↓	↓	17	0.01
		18	0.00
		19	0.00
		20	0.74
		21	0.97
		22	1.01
		23	1.01
		24	1.00

FLOW AND SEAL TEST PARAMETERS FOR TEST 221 ON 4/22/91

Parameter	LOCATION						
	Seal 1	Seal 2	Seal 3	Seal 4	Forward	Inner	Aft
Ω, Rpm	1494	1494	1494	1494	1494	1494	1494
P, psia	61.08	60.25	59.11	58.48	59.71	59.81	59.74
T, °R	514	515	513	513	517	515	519
Rho, lb/(ft^3)	0.321	0.316	0.311	0.308	0.312	0.313	0.311
Emdot, lb/sec	-0.333	-0.226	0.346	0.433	0.156	0.084	0.101
μ, lb/(ft sec)	1.18E-05	1.18E-05	1.18E-05	1.18E-05	1.19E-05	1.18E-05	1.19E-05
Ro, in	9.12	9.12	9.12	9.12	9.12	9.12	9.12
Vo, ft/sec	118.903	118.903	118.903	118.903	118.903	118.903	118.903
Vϕ, ft/sec	198.380	0	194.019	0	-	-	-
Vz, ft/sec	66.163	69.737	70.415	87.105	-	-	-
Qo, psi	0.489	0.489	0.489	0.489	0.489	0.489	0.489
δp/q	0	-1.696	-4.015	-5.308	-2.787	-2.596	-2.729
Vϕ/Vo	1.668	0	1.632	0	-	-	-
Vz/Vo	0.556	0.587	0.592	0.733	-	-	-
Reto	2.45E+06	2.45E+06	2.45E+06	2.45E+06	2.45E+06	2.45E+06	2.45E+06
Rer	-5897	-4004	6135	7690	2754	1480	1782
Rer/(Ret^0.8)	-0.046	-0.031	0.047	0.059	0.021	0.011	0.014
Mϕ	0.178	0	0.175	0	-	-	-
Coolant Gas	-	-	-	-	Air	Air	Air

GAS SOURCE CONCENTRATION

TEST	-	PORT	ϕ12
221	A	23	0.02
		24	0.95
		25	1.02
		26	1.00
		27	1.01
		28	1.01
		29	0.99
		30	1.01
		31	1.01

TEST	-	PORT	ϕ12
221	C	5	0.98
		17	0.01
		18	0.00
		19	0.00
		20	0.66
		21	0.95
		22	0.98
		23	0.99
		24	0.99

FLOW AND SEAL TEST PARAMETERS FOR TEST 222 ON 4/22/91

Parameter	LOCATION						
	Seal 1	Seal 2	Seal 3	Seal 4	Forward	Inner	Aft
Ω, Rpm	1493	1493	1493	1493	1493	1493	1493
P, psia	61.29	60.42	59.33	58.63	59.87	59.90	59.82
T, °R	515	515	517	517	520	516	520
Rho, lb/(ft^3)	0.321	0.317	0.310	0.306	0.311	0.314	0.311
Emdot, lb/sec	-0.325	-0.248	0.310	0.416	0.102	0.049	0.101
μ, lb/(ft sec)	1.18E-05	1.18E-05	1.19E-05	1.19E-05	1.19E-05	1.18E-05	1.19E-05
Ro, in	9.12	9.12	9.12	9.12	9.12	9.12	9.12
Vo, ft/sec	118.799	118.799	118.799	118.799	118.799	118.799	118.799
Vφ, ft/sec	194.244	0	194.645	0	-	-	-
Vz, ft/sec	64.784	69.574	70.642	87.785	-	-	-
Qo, psi	0.489	0.489	0.489	0.489	0.489	0.489	0.489
δp/q	0	-1.777	-3.999	-5.442	-2.898	-2.841	-2.998
Vφ/Vo	1.635	0	1.638	0	-	-	-
Vz/Vo	0.545	0.586	0.595	0.739	-	-	-
Reto	2.45E+06	2.45E+06	2.45E+06	2.45E+06	2.45E+06	2.45E+06	2.45E+06
Rer	-5752	-4381	5464	7336	1791	864	1774
Rer/(Ret^0.8)	-0.045	-0.034	0.042	0.057	0.014	0.007	0.014
Mφ	0.175	0	0.175	0	-	-	-
Coolant Gas	-	-	-	-	Air	Air	Air

GAS SOURCE CONCENTRATION

TEST	-	PORT	φ12
222	A	23	0.02
		24	0.68
		25	1.02
		26	1.02
		27	1.02
		28	1.01
		29	1.01
		30	1.01
		31	1.02

TEST	-	PORT	φ12
222	C	5	1.00
		17	0.00
		18	0.00
		19	0.00
		20	0.47
		21	0.82
		22	0.92
		23	0.99
		24	1.00

FLOW AND SEAL TEST PARAMETERS FOR TEST 223 ON 4/22/91

Parameter	LOCATION						
	Seal 1	Seal 2	Seal 3	Seal 4	Forward	Inner	Aft
Ω, Rpm	1492	1492	1492	1492	1492	1492	1492
P, psia	61.76	61.01	59.88	59.28	60.41	60.46	60.38
T, °R	520	520	518	518	523	520	523
Rho, lb/(ft^3)	0.320	0.316	0.312	0.309	0.312	0.314	0.312
Emdot, lb/sec	-0.311	-0.258	0.296	0.394	0.076	0.016	0.101
μ, lb/(ft sec)	1.19E-05	1.19E-05	1.19E-05	1.19E-05	1.20E-05	1.19E-05	1.20E-05
Ro, in	9.12	9.12	9.12	9.12	9.12	9.12	9.12
Vo, ft/sec	118.754	118.754	118.754	118.754	118.754	118.754	118.754
Vϕ, ft/sec	196.081	0.00	192.794	0	-	-	-
Vz, ft/sec	65.397	69.743	69.970	90.103	-	-	-
Qo, psi	0.487	0.487	0.487	0.487	0.487	0.487	0.487
δp/q	0	-1.539	-3.870	-5.100	-2.783	-2.686	-2.837
Vϕ/Vo	1.651	0	1.623	0	-	-	-
Vz/Vo	0.551	0.587	0.589	0.759	-	-	-
Reto	2.42E+06	2.42E+06	2.42E+06	2.42E+06	2.42E+06	2.42E+06	2.42E+06
Rer	-5456	-4522	5206	6931	1329	282	1768
Rer/(Ret^0.8)	-0.043	-0.035	0.041	0.054	0.010	0.002	0.014
Mϕ	0.175	0	0.173	0	-	-	-
Coolant Gas	-	-	-	-	Air	Air	Air

GAS SOURCE CONCENTRATION

TEST	-	PORT	ϕ12
223	A	23	-0.00
		24	0.47
		25	0.94
		26	0.94
		27	0.95
		28	0.93
		29	0.93
		30	0.94
		31	0.96

TEST	-	PORT	ϕ12
223	C	5	0.96
		17	-0.01
		18	-0.02
		19	-0.02
		20	0.36
		21	0.66
		22	0.75
		23	0.92
		24	0.94

FLOW AND SEAL TEST PARAMETERS FOR TEST 224 ON 4/22/91

	LOCATION						
Parameter	Seal 1	Seal 2	Seal 3	Seal 4	Forward	Inner	Aft
Ω, Rpm	1492	1492	1492	1492	1492	1492	1492
P, psia	61.70	60.84	59.71	59.07	60.20	60.23	60.15
T, °R	521	521	522	522	525	521	525
Rho, lb/(ft^3)	0.320	0.315	0.309	0.306	0.310	0.312	0.309
Emdot, lb/sec	-0.331	-0.260	0.293	0.399	0.046	0.034	0.101
μ, lb/(ft sec)	1.19E-05	1.19E-05	1.19E-05	1.19E-05	1.20E-05	1.19E-05	1.20E-05
Ro, in	9.12	9.12	9.12	9.12	9.12	9.12	9.12
Vo, ft/sec	118.757	118.757	118.757	118.757	118.757	118.757	118.757
Vϕ, ft/sec	195.673	0	194.843	0	-	-	-
Vz, ft/sec	65.261	69.914	70.714	87.748	-	-	-
Qo, psi	0.487	0.487	0.487	0.487	0.487	0.487	0.487
δp/q	0	-1.769	-4.094	-5.405	-3.091	-3.036	-3.192
Vϕ/Vo	1.648	0	1.641	0	-	-	-
Vz/Vo	0.550	0.589	0.595	0.739	-	-	-
Reto	2.42E+06	2.42E+06	2.42E+06	2.42E+06	2.42E+06	2.42E+06	2.42E+06
Rer	-5806	-4563	5141	6990	794	603	1755
Rer/(Ret^0.8)	-0.045	-0.036	0.040	0.055	0.006	0.005	0.014
Mϕ	0.175	0	0.174	0	-	-	-
Coolant Gas	-	-	-	-	Air	Air	Air

GAS SOURCE CONCENTRATION

TEST	-	PORT	ϕ12
224	A	23	0.01
		24	0.29
		25	0.96
		26	0.94
		27	0.96
		28	0.95
		29	0.92
		30	0.97
		31	1.01

TEST	-	PORT	ϕ12
224	C	5	0.98
		17	0.01
		18	0.01
		19	0.00
		20	0.31
		21	0.61
		22	0.70
		23	0.92
		24	0.97

FLOW AND SEAL TEST PARAMETERS FOR TEST 225 ON 4/08/91

Parameter	LOCATION						
	Seal 1	Seal 2	Seal 3	Seal 4	Forward	Inner	Aft
Ω, Rpm	1496	1496	1496	1496	1496	1496	1496
P, psia	61.60	60.81	59.67	59.16	60.11	60.15	60.12
T, °R	527	529	527	527	530	527	530
Rho, lb/(ft^3)	0.316	0.311	0.306	0.303	0.306	0.308	0.306
μ, lb/(ft sec)	1.20E-05	1.21E-05	1.21E-05	1.21E-05	1.21E-05	1.20E-05	1.21E-05
Ro, in	9.12	9.12	9.12	9.12	9.12	9.12	9.12
Vo, ft/sec	119.059	119.059	119.059	119.059	119.059	119.059	119.059
Vϕ, ft/sec	194.892	0	193.473	0	-	-	-
Vz, ft/sec	65.000	70.625	70.217	87.547	-	-	-
Qo, psi	0.483	0.483	0.483	0.483	0.483	0.483	0.483
δp/q	0	-1.637	-4.001	-5.073	-3.090	-3.001	-3.070
Vϕ/Vo	1.637	0	1.625	0	-	-	-
Vz/Vo	0.546	0.593	0.590	0.735	-	-	-
Reto	2.37E+06	2.37E+06	2.37E+06	2.37E+06	2.37E+06	2.37E+06	2.37E+06
Rer	-5.3E+03	-4.7E+03	4.84E+03	6.44E+03	1.73E+02	2.67E+02	1.72E+03
Rer/(Ret^0.8)	-0.042	-0.037	0.038	0.051	0.001	0.002	0.014
Mϕ	0.173	0	0.172	0	-	-	-
Coolant Gas	-	-	-	-	Air	Air	Air

GAS SOURCE CONCENTRATION

TEST	-	PORT	ϕ12
225	A	23	0.01
↓	↓	24	0.06
		25	0.54
		26	0.49
		27	0.52
		28	0.52
		29	0.50
		30	0.56
		31	0.72

TEST	-	PORT	ϕ12
225	C	5	0.99
↓	↓	17	0.03
		18	0.02
		19	0.02
		20	0.10
		21	0.21
		22	0.29
		23	0.53
		24	0.63

FLOW AND SEAL TEST PARAMETERS FOR TEST 231 ON 4/23/91

Parameter	LOCATION						
	Seal 1	Seal 2	Seal 3	Seal 4	Forward	Inner	Aft
Ω, Rpm	1494	1494	1494	1494	1494	1494	1494
P, psia	62.66	61.98	60.64	60.01	61.28	61.49	61.49
T, °R	528	528	527	527	530	530	530
Rho, lb/(ft^3)	0.320	0.317	0.311	0.307	0.312	0.313	0.313
Emdot, lb/sec	-0.291	-0.230	0.322	0.438	0.181	0.094	0.077
μ, lb/(ft sec)	1.21E-05	1.21E-05	1.20E-05	1.20E-05	1.21E-05	1.21E-05	1.21E-05
Ro, in	9.12	9.12	9.12	9.12	9.12	9.12	9.12
Vo, ft/sec	118.941	118.941	118.941	118.941	118.941	118.941	118.941
Vφ, ft/sec	192.464	0	191.786	0	-	-	-
Vz, ft/sec	64.191	68.358	69.605	83.825	-	-	-
Qo, psi	0.488	0.488	0.488	0.488	0.488	0.488	0.488
δp/q	0	-1.401	-4.137	-5.433	-2.834	-2.409	-2.410
Vφ/Vo	1.618	0	1.612	0	-	-	-
Vz/Vo	0.540	0.575	0.585	0.705	-	-	-
Reto	2.40E+06	2.40E+06	2.40E+06	2.40E+06	2.40E+06	2.40E+06	2.40E+06
Rer	-5055	-4002	5604	7607	3127	1621	1340
Rer/(Ret^0.8)	-0.040	-0.032	0.044	0.060	0.025	0.013	0.011
Mφ	0.171	0	0.170	0	-	-	-
Coolant Gas	-	-	-	-	Air	Air	Air

GAS SOURCE CONCENTRATION

TEST	-	PORT	φ14
231	B	1	1.03
↓	↓	3	0.98
		5	0.98
		7	0.98
		9	0.98

TEST	-	PORT	φ14
231	C	7	1.01
↓	↓	8	0.96
		9	0.94
		10	0.91
		11	0.69

FLOW AND SEAL TEST PARAMETERS FOR TEST 232 ON 4/23/91

Parameter	LOCATION						
	Seal 1	Seal 2	Seal 3	Seal 4	Forward	Inner	Aft
Ω, Rpm	1494	1494	1494	1494	1494	1494	1494
P, psia	62.46	61.79	60.54	59.88	61.13	61.26	61.19
T, °R	528	527	526	526	530	529	531
Rho, lb/(ft^3)	0.319	0.317	0.311	0.307	0.311	0.313	0.311
Emdot, lb/sec	-0.328	-0.234	0.336	0.433	0.180	0.094	0.067
μ, lb/(ft sec)	1.21E-05	1.20E-05	1.20E-05	1.20E-05	1.21E-05	1.21E-05	1.21E-05
Ro, in	9.12	9.12	9.12	9.12	9.12	9.12	9.12
Vo, ft/sec	118.912	118.912	118.912	118.912	118.912	118.912	118.912
Vϕ, ft/sec	196.522	0	192.312	0	-	-	-
Vz, ft/sec	65.544	69.004	69.796	86.506	-	-	-
Qo, psi	0.487	0.487	0.487	0.487	0.487	0.487	0.487
δp/q	0	-1.384	-3.963	-5.310	-2.743	-2.465	-2.623
Vϕ/Vo	1.653	0	1.617	0	-	-	-
Vz/Vo	0.551	0.580	0.587	0.727	-	-	-
Reto	2.39E+06	2.39E+06	2.39E+06	2.39E+06	2.39E+06	2.39E+06	2.39E+06
Rer	-5686	-4062	5851	7528	3119	1622	1165
Rer/(Ret^0.8)	-0.045	-0.032	0.046	0.059	0.025	0.013	0.009
Mϕ	0.174	0	0.171	0	-	-	-
Coolant Gas	-	-	-	-	Air	Air	Air

GAS SOURCE CONCENTRATION

TEST	-	PORT	ϕ14
232	B	1	1.03
		3	0.96
		5	0.95
		7	0.95
		9	0.94

TEST	-	PORT	ϕ14
232	C	7	0.98
		8	0.92
		9	0.89
		10	0.82
		11	0.60

FLOW AND SEAL TEST PARAMETERS FOR TEST 233 ON 4/23/91

Parameter	LOCATION						
	Seal 1	Seal 2	Seal 3	Seal 4	Forward	Inner	Aft
Ω, Rpm	1493	1493	1493	1493	1493	1493	1493
P, psia	62.38	61.59	60.37	59.73	60.98	61.15	61.07
T, °R	528	528	528	528	530	529	531
Rho, lb/(ft^3)	0.319	0.315	0.308	0.305	0.311	0.312	0.310
Emdot, lb/sec	-0.297	-0.226	0.341	0.427	0.180	0.093	0.058
μ, lb/(ft sec)	1.21E-05	1.21E-05	1.21E-05	1.21E-05	1.21E-05	1.21E-05	1.21E-05
Ro, in	9.12	9.12	9.12	9.12	9.12	9.12	9.12
Vo, ft/sec	118.856	118.856	118.856	118.856	118.856	118.856	118.856
Vϕ, ft/sec	192.467	0	195.116	0	-	-	-
Vz, ft/sec	64.192	69.496	70.813	87.564	-	-	-
Qo, psi	0.486	0.486	0.486	0.486	0.486	0.486	0.486
δp/q	0	-1.625	-4.141	-5.457	-2.887	-2.538	-2.706
Vϕ/Vo	1.619	0	1.642	0	-	-	-
Vz/Vo	0.540	0.585	0.596	0.737	-	-	-
Reto	2.39E+06	2.39E+06	2.39E+06	2.39E+06	2.39E+06	2.39E+06	2.39E+06
Rer	-5167	-3929	5911	7405	3115	1618	994
Rer/(Ret^0.8)	-0.041	-0.031	0.047	0.058	0.025	0.013	0.008
Mϕ	0.171	0	0.173	0	-	-	-
Coolant Gas	-	-	-	-	Air	Air	Air

GAS SOURCE CONCENTRATION

TEST	-	PORT	ϕ14
233	B	1	1.07
↓	↓	3	0.95
		5	0.95
		7	0.95
		9	0.94

TEST	-	PORT	ϕ14
233	C	7	1.00
↓	↓	8	0.92
		9	0.90
		10	0.78
		11	0.55

FLOW AND SEAL TEST PARAMETERS FOR TEST 234 ON 4/23/91

Parameter	LOCATION						
	Seal 1	Seal 2	Seal 3	Seal 4	Forward	Inner	Aft
Ω, Rpm	1494	1494	1494	1494	1494	1494	1494
P, psia	62.22	61.49	60.32	59.69	60.91	61.04	60.94
T, °R	527	527	528	528	529	527	531
Rho, lb/(ft^3)	0.319	0.315	0.308	0.305	0.311	0.313	0.310
Emdot, lb/sec	-0.315	-0.234	0.337	0.430	0.180	0.093	0.048
μ, lb/(ft sec)	1.20E-05	1.20E-05	1.21E-05	1.21E-05	1.21E-05	1.20E-05	1.21E-05
Ro, in	9.12	9.12	9.12	9.12	9.12	9.12	9.12
Vo, ft/sec	118.896	118.896	118.896	118.896	118.896	118.896	118.896
Vφ, ft/sec	195.963	0	195.330	0	-	-	-
Vz, ft/sec	65.358	69.787	70.891	86.768	-	-	-
Qo, psi	0.486	0.486	0.486	0.486	0.486	0.486	0.486
δp/q	0	-1.510	-3.901	-5.196	-2.685	-2.425	-2.626
Vφ/Vo	1.648	0	1.643	0	-	-	-
Vz/Vo	0.550	0.587	0.596	0.730	-	-	-
Reto	2.39E+06	2.39E+06	2.39E+06	2.39E+06	2.39E+06	2.39E+06	2.39E+06
Rer	-5470	-4065	5851	7468	3124	1622	827
Rer/(Ret^0.8)	-0.043	-0.032	0.046	0.059	0.025	0.013	0.007
Mφ	0.174	0	0.173	0	-	-	-
Coolant Gas	-	-	-	-	Air	Air	Air

GAS SOURCE CONCENTRATION

TEST	-	PORT	φ14
234	B	1	1.12
↓	↓	3	0.96
		5	0.95
		7	0.95
		9	0.94

TEST	-	PORT	φ14
234	C	7	1.04
↓	↓	8	0.92
		9	0.88
		10	0.73
		11	0.50

FLOW AND SEAL TEST PARAMETERS FOR TEST 235 ON 4/23/91

Parameter	LOCATION						
	Seal 1	Seal 2	Seal 3	Seal 4	Forward	Inner	Aft
Ω, Rpm	1494	1494	1494	1494	1494	1494	1494
P, psia	62.44	61.56	60.35	59.77	60.96	61.09	60.99
T, °R	526	526	527	527	530	526	530
Rho, lb/(ft^3)	0.321	0.316	0.309	0.306	0.311	0.313	0.311
Emdot, lb/sec	-0.310	-0.234	0.315	0.456	0.180	0.093	0.029
μ, lb/(ft sec)	1.20E-05	1.20E-05	1.20E-05	1.20E-05	1.21E-05	1.20E-05	1.21E-05
Ro, in	9.12	9.12	9.12	9.12	9.12	9.12	9.12
Vo, ft/sec	118.870	118.870	118.870	118.870	118.870	118.870	118.870
Vφ, ft/sec	192.041	0	195.070	0	-	-	-
Vz, ft/sec	64.050	69.711	70.796	87.207	-	-	-
Qo, psi	0.488	0.488	0.488	0.488	0.488	0.488	0.488
δp/q	0	-1.792	-4.278	-5.453	-3.015	-2.747	-2.963
Vφ/Vo	1.616	0	1.641	0	-	-	-
Vz/Vo	0.539	0.586	0.596	0.734	-	-	-
Reto	2.41E+06	2.41E+06	2.41E+06	2.41E+06	2.41E+06	2.41E+06	2.41E+06
Rer	-5393	-4077	5471	7936	3120	1626	497
Rer/(Ret^0.8)	-0.042	-0.032	0.043	0.062	0.024	0.013	0.004
Mφ	0.171	0	0.173	0	-	-	-
Coolant Gas	-	-	-	-	Air	Air	Air

GAS SOURCE CONCENTRATION

TEST	-	PORT	φ14
235	B	1	1.15
		3	0.87
		5	0.83
		7	0.78
		9	0.80

TEST	-	PORT	φ14
235	C	7	0.98
		8	0.78
		9	0.75
		10	0.50
		11	0.41

FLOW AND SEAL TEST PARAMETERS FOR TEST 241 ON 4/25/91

Parameter	LOCATION						
	Seal 1	Seal 2	Seal 3	Seal 4	Forward	Inner	Aft
Ω, Rpm	1499	1499	1499	1499	1499	1499	1499
P, psia	62.31	61.57	60.31	59.70	60.95	61.08	61.03
T, °R	531	531	531	531	531	531	531
Rho, lb/(ft^3)	0.317	0.313	0.306	0.303	0.310	0.311	0.310
Emdot, lb/sec	-0.295	-0.216	0.337	0.418	0.183	0.103	0.105
μ, lb/(ft sec)	1.21E-05	1.21E-05	1.21E-05	1.21E-05	1.21E-05	1.21E-05	1.21E-05
Ro, in	9.12	9.12	9.12	9.12	9.12	9.12	9.12
Vo, ft/sec	119.328	119.328	119.328	119.328	119.328	119.328	119.328
Vϕ, ft/sec	192.332	0	193.384	0	-	-	-
Vz, ft/sec	64.147	69.331	70.185	87.225	-	-	-
Qo, psi	0.486	0.486	0.486	0.486	0.486	0.486	0.486
δp/q	0	-1.521	-4.105	-5.361	-2.797	-2.518	-2.623
Vϕ/Vo	1.612	0	1.621	0	-	-	-
Vz/Vo	0.538	0.581	0.588	0.731	-	-	-
Reto	2.37E+06	2.37E+06	2.37E+06	2.37E+06	2.37E+06	2.37E+06	2.37E+06
Rer	-5106	-3739	5821	7212	3158	1781	1807
Rer/(Ret^0.8)	-0.041	-0.030	0.046	0.057	0.025	0.014	0.014
Mϕ	0.170	0	0.171	0	-	-	-
Coolant Gas	-	-	-	-	Air	Air	CO_2

GAS SOURCE CONCENTRATION

TEST	-	PORT	ϕ14
241	B	1	0.97
↓	↓	3	0.90
		5	0.90
		7	0.89
		9	0.89

TEST	-	PORT	ϕ14
241	C	7	0.92
↓	↓	8	0.86
		9	0.83
		10	0.71
		11	0.54

FLOW AND SEAL TEST PARAMETERS FOR TEST 243 ON 4/25/91

Parameter	LOCATION						
	Seal 1	Seal 2	Seal 3	Seal 4	Forward	Inner	Aft
Ω, Rpm	1497	1497	1497	1497	1497	1497	1497
P, psia	62.43	61.73	60.49	59.86	61.14	61.29	61.19
T, °R	533	533	532	532	531	532	531
Rho, lb/(ft^3)	0.316	0.312	0.307	0.304	0.311	0.311	0.311
Emdot, lb/sec	-0.301	-0.222	0.342	0.423	0.182	0.103	0.105
μ, lb/(ft sec)	1.22E-05	1.22E-05	1.21E-05	1.21E-05	1.21E-05	1.21E-05	1.21E-05
Ro, in	9.12	9.12	9.12	9.12	9.12	9.12	9.12
Vo, ft/sec	119.166	119.166	119.166	119.166	119.166	119.166	119.166
Vφ, ft/sec	194.794	0	194.545	0	-	-	-
Vz, ft/sec	64.968	69.692	70.606	87.027	-	-	-
Qo, psi	0.484	0.484	0.484	0.484	0.484	0.484	0.484
δp/q	0	-1.444	-4.002	-5.314	-2.659	-2.355	-2.573
Vφ/Vo	1.635	0	1.633	0	-	-	-
Vz/Vo	0.545	0.585	0.592	0.730	-	-	-
Reto	2.36E+06	2.36E+06	2.36E+06	2.36E+06	2.36E+06	2.36E+06	2.36E+06
Rer	-5195	-3829	5895	7295	3151	1775	1810
Rer/(Ret^0.8)	-0.041	-0.031	0.047	0.058	0.025	0.014	0.014
Mφ	0.172	0	0.172	0	-	-	-
Coolant Gas	-	-	-	-	Air	Air	CO_2

GAS SOURCE CONCENTRATION

TEST	-	PORT	φ14
243	B	1	0.97
		3	0.90
		5	0.89
		7	0.89
		9	0.89

TEST	-	PORT	φ14
243	C	7	0.92
		8	0.85
		9	0.82
		10	0.70
		11	0.54

FLOW AND SEAL TEST PARAMETERS FOR TEST 244 ON 4/25/91

Parameter	LOCATION						
	Seal 1	Seal 2	Seal 3	Seal 4	Forward	Inner	Aft
Ω, Rpm	1496	1496	1496	1496	1496	1496	1496
P, psia	62.58	61.77	60.56	59.96	61.22	61.35	61.27
T, °R	531	531	536	536	532	531	531
Rho, lb/(ft^3)	0.318	0.314	0.305	0.302	0.311	0.312	0.311
Emdot, lb/sec	-0.325	-0.219	0.333	0.410	0.182	0.103	0.083
μ, lb/(ft sec)	1.21E-05	1.21E-05	1.22E-05	1.22E-05	1.21E-05	1.21E-05	1.21E-05
Ro, in	9.12	9.12	9.12	9.12	9.12	9.12	9.12
Vo, ft/sec	119.090	119.090	119.090	119.090	119.090	119.090	119.090
Vϕ, ft/sec	196.012	0	195.274	0	-	-	-
Vz, ft/sec	65.374	69.358	70.870	88.248	-	-	-
Qo, psi	0.486	0.486	0.486	0.486	0.486	0.486	0.486
δp/q	0	-1.648	-4.153	-5.375	-2.789	-2.510	-2.683
Vϕ/Vo	1.646	0	1.640	0	-	-	-
Vz/Vo	0.549	0.582	0.595	0.741	-	-	-
Reto	2.37E+06	2.37E+06	2.37E+06	2.37E+06	2.37E+06	2.37E+06	2.37E+06
Rer	-5614	-3788	5718	7046	3151	1778	1436
Rer/(Ret^0.8)	-0.045	-0.030	0.045	0.056	0.025	0.014	0.011
Mϕ	0.173	0	0.172	0	-	-	-
Coolant Gas	-	-	-	-	Air	Air	CO_2

GAS SOURCE CONCENTRATION

TEST	-	PORT	ϕ14
244	B	1	0.97
↓	↓	3	0.85
		5	0.84
		7	0.83
		9	0.83

TEST	-	PORT	ϕ14
244	C	7	0.89
↓	↓	8	0.79
		9	0.76
		10	0.61
		11	0.46

FLOW AND SEAL TEST PARAMETERS FOR TEST 246 ON 4/25/91

Parameter	LOCATION						
	Seal 1	Seal 2	Seal 3	Seal 4	Forward	Inner	Aft
Ω, Rpm	1496	1496	1496	1496	1496	1496	1496
P, psia	62.66	61.79	60.57	59.95	61.18	61.31	61.23
T, °R	536	536	537	537	534	535	536
Rho, lb/(ft^3)	0.316	0.311	0.304	0.301	0.309	0.309	0.308
Emdot, lb/sec	-0.310	-0.222	0.341	0.410	0.183	0.103	0.035
μ, lb/(ft sec)	1.22E-05	1.22E-05	1.22E-05	1.22E-05	1.22E-05	1.22E-05	1.22E-05
Ro, in	9.12	9.12	9.12	9.12	9.12	9.12	9.12
Vo, ft/sec	119.099	119.099	119.099	119.099	119.099	119.099	119.099
Vφ, ft/sec	195.763	0	198.911	0	-	-	-
Vz, ft/sec	65.291	70.475	72.191	89.125			
Qo, psi	0.483	0.483	0.483	0.483	0.483	0.483	0.483
δp/q	0	-1.797	-4.318	-5.605	-3.065	-2.787	-2.951
Vφ/Vo	1.644	0	1.670	0	-	-	-
Vz/Vo	0.548	0.592	0.606	0.748	-	-	-
Reto	2.34E+06	2.34E+06	2.34E+06	2.34E+06	2.34E+06	2.34E+06	2.34E+06
Rer	-5318	-3806	5843	7030	3146	1771	607
Rer/(Ret^0.8)	-0.043	-0.031	0.047	0.056	0.025	0.014	0.005
Mφ	0.172	0	0.175	0	-	-	-
Coolant Gas	-	-	-	-	Air	Air	CO_2

GAS SOURCE CONCENTRATION

TEST	-	PORT	φ14
246	B	1	0.96
↓	↓	3	0.60
		5	0.57
		7	0.57
		9	0.55

TEST	-	PORT	φ14
246	C	7	0.67
↓	↓	8	0.52
		9	0.49
		10	0.34
		11	0.23

FLOW AND SEAL TEST PARAMETERS FOR TEST 245 ON 4/08/91

Parameter	LOCATION Seal 1	Seal 2	Seal 3	Seal 4	Forward	Inner	Aft
Ω, Rpm	1495	1495	1495	1495	1495	1495	1495
P, psia	47.80	47.03	45.75	45.15	46.37	46.52	46.41
T, °R	534	534	534	534	531	532	532
Rho, lb/(ft^3)	0.242	0.238	0.231	0.228	0.236	0.236	0.235
μ, lb/(ft sec)	1.22E-05	1.22E-05	1.22E-05	1.22E-05	1.21E-05	1.21E-05	1.21E-05
Ro, in	9.12	9.12	9.12	9.12	9.12	9.12	9.12
Vo, ft/sec	119.013	119.013	119.013	119.013	119.013	119.013	119.013
Vϕ, ft/sec	227.862	0	230.997	0	-	-	-
Vz, ft/sec	75.996	81.552	83.836	103.519	-	-	-
Qo, psi	0.369	0.369	0.369	0.369	0.369	0.369	0.369
δp/q	0	-2.076	-5.555	-7.164	-3.858	-3.452	-3.746
Vϕ/Vo	1.915	0	1.941	0	-	-	-
Vz/Vo	0.639	0.685	0.704	0.870	-	-	-
Reto	1.80E+06	1.80E+06	1.80E+06	1.80E+06	1.80E+06	1.80E+06	1.80E+06
Rer	-7.1E+03	-3.6E+03	3.35E+03	5.62E+03	2.83E+03	1.59E+03	8.92E+02
Rer/(Ret^0.8)	-0.071	-0.036	0.033	0.056	0.028	0.016	0.009
Mϕ	0.173	0	0.172	0	-	-	-
Coolant Gas	-	-	-	-	Air	Air	CO_2

GAS SOURCE CONCENTRATION

TEST	-	PORT	ϕ14
245	B	1	0.96
↓	↓	3	0.74
		5	0.72
		7	0.71
		9	0.71

TEST	-	PORT	ϕ14
245	C	7	0.85
↓	↓	8	0.66
		9	0.64
		10	0.47
		11	0.34

FLOW AND SEAL TEST PARAMETERS FOR TEST 247 ON 4/25/91

Parameter	LOCATION						
	Seal 1	Seal 2	Seal 3	Seal 4	Forward	Inner	Aft
Ω, Rpm	1496	1496	1496	1496	1496	1496	1496
P, psia	62.59	61.73	60.48	59.92	61.08	61.26	61.65
T, °R	536	536	537	537	536	536	536
Rho, lb/(ft^3)	0.315	0.311	0.304	0.301	0.308	0.309	0.310
Emdot, lb/sec	-0.316	-0.226	0.332	0.407	0.183	0.103	0.024
μ, lb/(ft sec)	1.22E-05	1.22E-05	1.22E-05	1.22E-05	1.22E-05	1.22E-05	1.22E-05
Ro, in	9.12	9.12	9.12	9.12	9.12	9.12	9.12
Vo, ft/sec	119.024	119.024	119.024	119.024	119.024	119.024	119.024
Vϕ, ft/sec	196.574	0	198.170	0	-	-	-
Vz, ft/sec	65.561	70.671	71.922	88.703	-	-	-
Qo, psi	0.482	0.482	0.482	0.482	0.482	0.482	0.482
δp/q	0	-1.786	-4.389	-5.541	-3.134	-2.763	-1.961
Vϕ/Vo	1.652	0	1.665	0	-	-	-
Vz/Vo	0.551	0.594	0.604	0.745	-	-	-
Reto	2.34E+06	2.34E+06	2.34E+06	2.34E+06	2.34E+06	2.34E+06	2.34E+06
Rer	-5421	-3877	5694	6978	3133	1766	404
Rer/(Ret^0.8)	-0.044	-0.031	0.046	0.056	0.025	0.014	0.003
Mϕ	0.173	0	0.174	0	-	-	-
Coolant Gas	-	-	-	-	Air	Air	CO_2

GAS SOURCE CONCENTRATION

TEST	-	PORT	ϕ14
247	B	1	0.95
↓	↓	3	0.49
		5	0.46
		7	0.46
		9	0.43

TEST	-	PORT	ϕ14
247	C	7	0.54
↓	↓	8	0.41
		9	0.39
		10	0.24
		11	0.16

FLOW AND SEAL TEST PARAMETERS FOR TEST 248 ON 4/08/91

Parameter	LOCATION						
	Seal 1	Seal 2	Seal 3	Seal 4	Forward	Inner	Aft
Ω, Rpm	1495	1495	1495	1495	1495	1495	1495
P, psia	62.81	61.99	60.71	60.14	61.35	61.47	61.39
T, °R	536	536	536	536	534	535	536
Rho, lb/(ft^3)	0.316	0.312	0.306	0.303	0.310	0.310	0.309
μ, lb/(ft sec)	1.22E-05	1.22E-05	1.22E-05	1.22E-05	1.22E-05	1.22E-05	1.22E-05
Ro, in	9.12	9.12	9.12	9.12	9.12	9.12	9.12
Vo, ft/sec	118.962	118.962	118.962	118.962	118.962	118.962	118.962
Vφ, ft/sec	202.119	0	199.313	0	-	-	-
Vz, ft/sec	67.411	71.525	72.336	88.992	-	-	-
Qo, psi	0.483	0.483	0.483	0.483	0.483	0.483	0.483
δp/q	0	-1.711	-4.346	-5.545	-3.036	-2.791	-2.953
Vφ/Vo	1.699	0	1.675	0	-	-	-
Vz/Vo	0.567	0.601	0.608	0.748	-	-	-
Reto	2.34E+06	2.34E+06	2.34E+06	2.34E+06	2.34E+06	2.34E+06	2.34E+06
Rer	-6.6E+03	-4.0E+03	4.98E+03	7.31E+03	3.15E+03	1.77E+03	8.12E+02
Rer/(Ret^0.8)	-0.053	-0.032	0.040	0.059	0.025	0.014	0.007
Mφ	0.178	0	0.176	0	-	-	-
Coolant Gas	-	-	-	-	Air	Air	CO_2

GAS SOURCE CONCENTRATION

TEST	-	PORT	φ14
248	B	1	0.95
↓	↓	3	0.65
		5	0.62
		7	0.62
		9	0.60

TEST	-	PORT	φ14
248	C	7	0.74
↓	↓	8	0.56
		9	0.54
		10	0.39
		11	0.27

FLOW AND SEAL TEST PARAMETERS FOR TEST 249 ON 4/08/91

Parameter	LOCATION						
	Seal 1	Seal 2	Seal 3	Seal 4	Forward	Inner	Aft
Ω, Rpm	1496	1496	1496	1496	1496	1496	1496
P, psia	62.83	62.08	60.82	60.21	61.48	61.59	61.49
T, °R	537	536	536	536	536	536	537
Rho, lb/(ft^3)	0.316	0.313	0.306	0.303	0.310	0.310	0.309
μ, lb/(ft sec)	1.22E-05	1.22E-05	1.22E-05	1.22E-05	1.22E-05	1.22E-05	1.22E-05
Ro, in	9.12	9.12	9.12	9.12	9.12	9.12	9.12
Vo, ft/sec	119.037	119.037	119.037	119.037	119.037	119.037	119.037
Vϕ, ft/sec	195.119	0	197.333	0	-	-	-
Vz, ft/sec	65.076	69.124	71.618	88.052	-	-	-
Qo, psi	0.483	0.483	0.483	0.483	0.483	0.483	0.483
δp/q	0	-1.556	-4.173	-5.440	-2.799	-2.567	-2.789
Vϕ/Vo	1.639	0	1.658	0	-	-	-
Vz/Vo	0.547	0.581	0.602	0.740	-	-	-
Reto	2.34E+06	2.34E+06	2.34E+06	2.34E+06	2.34E+06	2.34E+06	2.34E+06
Rer	-5.8E+03	-3.6E+03	4.79E+03	7.10E+03	3.14E+03	1.77E+03	1.22E+03
Rer/(Ret^0.8)	-0.046	-0.029	0.038	0.057	0.025	0.014	0.010
Mϕ	0.172	0	0.174	0	-	-	-
Coolant Gas	-	-	-	-	Air	Air	CO_2

GAS SOURCE CONCENTRATION

TEST	-	PORT	ϕ14
249	B	1	0.95
↓	↓	3	0.77
		5	0.75
		7	0.75
		9	0.74

TEST	-	PORT	ϕ14
249	C	7	0.85
↓	↓	8	0.70
		9	0.67
		10	0.55
		11	0.40

8.0 LIST OF SYMBOLS

m	Flow Rate, lb/sec
P	Static Pressure, psia
P_{ref}	Static Reference Pressure, psia
q_{ref}	Dynamic Reference Pressure = 0.5ρ ref $\Omega^2 R_o^2$, psia
Re_t	Tangential Reynolds Number = $\rho \Omega R_o^2/\mu$
Re_m	Dimensionless Flow Rate = $m/(2\pi R_o \mu)$
R_o	Blade Platform Upper Radius, in
T	Static Temperature, °R
V_o	Disk Tangential Velocity at R_o, ft/sec
V_ϕ	Fluid Tangential Velocity (Absolute) at R_o, ft/sec
V_z	fluid Axial Velocity at R_o, ft/sec
Ω	Disk Rotation Rate, radians/sec
η_i	Non-Dimensional Flow Parameter = $Re_m/Re_t^{0.8}$
ϕ_i	Measured Concentration Fraction of Gas From Source i

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16. Abstract

An experimental investigation of turbine disk cavity aerodynamics and heat transfer was conducted to provide an experimental data base that can guide the aerodynamic and thermal design of turbine disks and blade attachments for flow conditions and geometries simulating those of SSME turbopump drive turbines. Experiments were conducted to define the nature of the aerodynamics and heat transfer of the flow within the disk cavities and blade attachments of a large scale model simulating the SSME turbopump drive turbines. These experiments include flow between the main gas path and the disk cavities, flow within the disk cavities, and leakage flows through the blade attachments and labyrinth seals. Air was used to simulate the combustion products in the gas path. Air and carbon dioxide were used to simulate the coolants injected at three locations in the disk cavities. Trace amounts of carbon dioxide were used to determine the source of the gas at selected locations on the rotors, the cavity walls and the interstage seal. The measurements on the rotor and stationary walls in the forward and aft cavities showed that the coolant effectiveness was 90 percent or greater when the coolant flow rate was greater than the local free disk entrainment flow rate and when room temperature air was used as both coolant and gas path fluid. When a coolant-to-gas-path density ratio of 1.51 was used in the aft cavity, the coolant effectiveness on the rotor was also 90 percent or greater at the aforementioned condition. However, the coolant concentration on the stationary wall was 60 to 80 percent at the aforementioned condition indicating a more rapid mixing of the coolant and flow through the rotor shank passages. This increased mixing rate was attributed to the destabilizing effects of the adverse density gradients.

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